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CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER

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VOL. I · NO. 3

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RÉDIGÉ PAR

E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

AOÛT 1926

Note.

The Journal of the Council will, it is hoped, appear quarterly, and four numbers will form a volume. It will include in addition to general articles, reviews and bibliography, the special papers hitherto issued in the series of "Publications de Circonstance".

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IMPRIMERIE BIANCO LUNO

L'Amiral Augusto Eduardo Neuparth.

Notices necrologiques.

L'Amiral Augusto Eduardo Neuparth.

C'est en 1923 que la République portugaise, ayant donné son adhésion au Conseil International pour l'Exploration de la Mer, commença d'une façon effective à collaborer aux recherches du Plateau Continental Atlantique.

Aussi convient-il de saluer la mémoire d'un des hommes qui fut le promoteur le plus actif de la participation du Portugal aux recherches océanographiques.

L'amiral Augusto Eduardo Neuparth naquit à Lisbonne en 1869. Elève à l'école navale, il est ingénieur hydrographe en 1885. A partir de cette époque, ses doubles qualités de marin et d'ingénieur lui font confier par son gouvernement de multiples missions. On le trouve capitaine des ports de l'Inde portugaise; mais il se révéla surtout dans les colonies africaines.

Ses travaux hydrographiques les plus remarquables furent faits en Guinée et dans les possessions portugaises sud-africaines, autour de Cabinda, de St. Pol de Loanda et de Lourenço-Marquès. Il fit partie de la Commission de délimitation des frontières dans cette dernière possession.

Malgré son âge déjà avancé, l'Amiral Neuparth prit part à la guerre 1914—1918 et fut, pendant quelques mois, chef de la base navale des Açores.

Très apprécié par le gouvernement portugais, il fut ministre de la Marine, en 1914, puis devint directeur général de ce département, fonction qu'il exerça jusqu'à sa mort. Il fit partie de la suite du Président de la République portugaise Antonio José de Almeida, lors de la visite officielle de celui-ci au Brésil, de même il fut désigné pour accompagner S. A. S. Albert Ier, prince de Monaco, lors de sa visite au Portugal en 1923.

L'Amiral NEUPARTH fut un des créateurs du service météorologique de la Marine. Il créa la Revue Mensuelle "Pesca Maritima", consacrée à la pêche; enfin il fut le délégué du Portugal dans le Conseil International pour l'Exploration de la Mer.

Au mois d'août 1925, l'Amiral NEUPARTH mourait à Lisbonne.

Il emporte le souvenir ému de tous ceux qui l'ont connu et approché. Ses voyages, comme explorateur et comme marin, sa carrière politique, ses missions nombreuses, lui avaient donné cette sagesse aimable et indulgente qui ne se rencontre que chez ceux qui ont eu à apprécier et diriger des quantités d'hommes. Un sourire très fin accueillait cordialement ceux qu'aurait pu impressionner son visage rigide de marin. A côté de l'homme d'action énergique et toujours prêt à prendre de graves responsabilités, on sentait l'esprit calme et doux du savant.

L'Amiral NEUPARTH a accompli dans sa longue carrière tout le programme qu'il s'était tracé dès sa jeunesse en se consacrant à la vocation de marin et d'hydrographe, et à ce double titre s'est montré en tous points digne de son pays. Son souvenir restera vivant parmi les membres du Conseil International pour l'Exploration de la Mer, parmi lesquels il ne comptait que des amis.

Miss Sigrid Hansen.

All those connected with the International Council will have learnt with the deepest regret of the death of Miss Hansen on the 16th of June last, at the early age of 51.

For 17 years she served the Council as Second Assistant Secretary of the Bureau. In that capacity her ability, her industry, and her knowledge of foreign languages made her an invaluable lieutenant. But the delegates and experts with whom her work brought her in contact will longest remember her pleasant unassuming personality, always cheerful, never ruffled, ever ready to help in small things as in great. She was one of those persons who so fit into their surroundings that one takes them for granted and does not realise till they are gone how great a gap has been caused by their departure.

A quantitative consideration of some factors concerned in plant growth in water

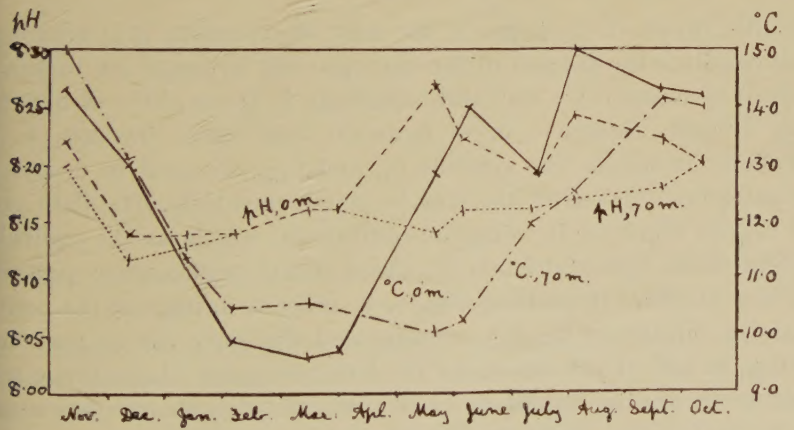
by

W. R. G. Atkins.
Marine Biological Laboratory, Plymouth.

PART II. SOME CHEMICAL FACTORS[1])

Carbon dioxide assimilation and the alkalinity of sea water.

The energy supplied by the light enables the plankton and the fixed algae to carry on photosynthesis. They derive their carbon ioxide from that in solution in the water, which is continuously re-lenished by the hydrolysis of bicarbonates, the water becoming progress-ely more alkaline. Rise of temperature, which lessens the solubility f carbon dioxide has the same effect and necessitates the introduction



ig. 6. Seasonal changes at Station E 1, surface and bottom, Nov. 1921 to Oct. 1922 for temperature and pH value.

f a correction before the observed seasonal change in alkalinity can e put down as due to photosynthesis. Fig. 6 shows the seasonal changes n the pH value and temperature of the sea at Station E 1, it may be

[1]) Part I appeared in the Journal, Vol. I, No. 2, pp. 99—126.

noticed that the vernal rise in alkalinity reaches its maximum lon before the temperature maximum is reached. Bad weather brough about a lowering of the alkalinity, partly due to mixing with deepe water. Fig. 7 illustrates this, showing the straightening out of the pH depth curve in July. It is seen that in general the alteration in alkalinit is a phenomenon of the upper twenty metres, which is gradually extende to the deeper water by mixing. This conclusion is supported by th evidence of the temperature changes.

It should be mentioned that the symbol pH denotes the logarithn of the reciprocal of the hydrogen ion concentration expressed in gram

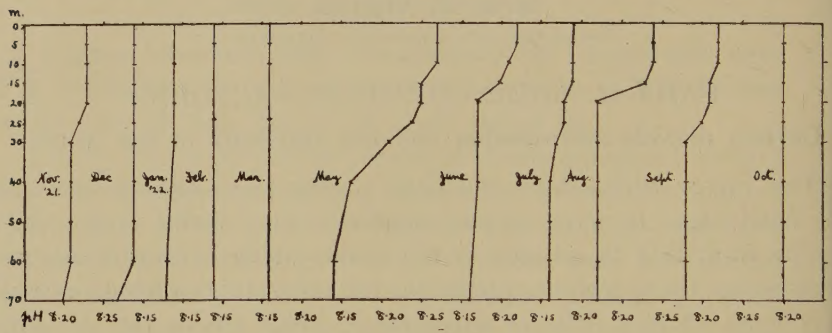


Fig. 7. Variation of pH value with depth at Station E 1, Nov. 1921 to Oct. 192

per litre, which for hydrogen is the same as expressing it in gram equi valents. Since the product of the hydrogen and hydroxyl ion concentra tions is a constant, we may state alkalinity in terms either of hydroge ions — which decrease — or of hydroxyl ions, which increase, as th alkalinity increases. The symbols C_H and C_{OH} are used to denote th actual concentrations of the ions in gram-equivalents. The data give for C_{OH} in Fig. 8 are in milligram-equivalents, which, as the equivalen weight of the hydroxyl ion is 17, afford actual weights when multiplie by this number. In plotting Fig. 8, in order to bring out the relatio between duration of the day, sunshine and alkalinity, use has been mad of C_{OH} as well as pH values, for the latter being on a logarithmic scal tend to render the magnitude of the concentration changes less readil understood. Since, however, natural waters range from about pH 4. in bogs to pH 9.6 in calcareous ponds subject to intense photosynthet activity, it is convenient to use the logarithmic scale, especially fo graphic representation, as the changes amount to one hundred thousan fold. Fig. 8 also shows the reduction in carbon dioxide pressure corre ponding to such alterations in alkalinity as are plotted above, the form being obtained from scales constructed by McClendon (1917) for th

equilibrium pressures of various bicarbonate solutions. His buffer mixtures were also used in carrying out the pH determinations.

Inspection of Fig. 8 renders it evident that there is a causal connection

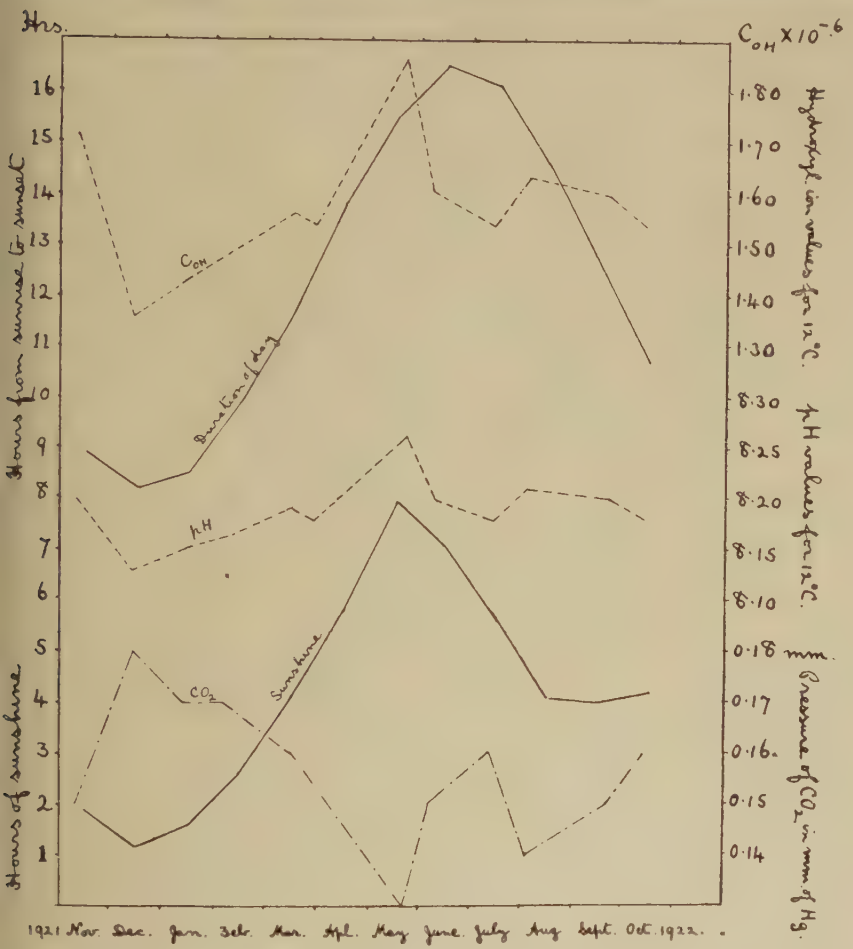


Fig. 8. Seasonal changes at Station E1, surface. The C_{OH} concentrations and the CO_2 pressures have been deduced from the pH measurements. The data for sunshine and duration of the day are taken from the records for England S.W. area and have been plotted as values for the 15th day of each month.

between the increase in alkalinity and the onset of long days with abundance of sunshine. The dip in the alkalinity curve for July, noticed already in Figs. 6 and 7 did not occur in 1923, for which year the observed surface maximum was slightly lower than in 1922 and was recorded for early July, instead of the latter part of May.

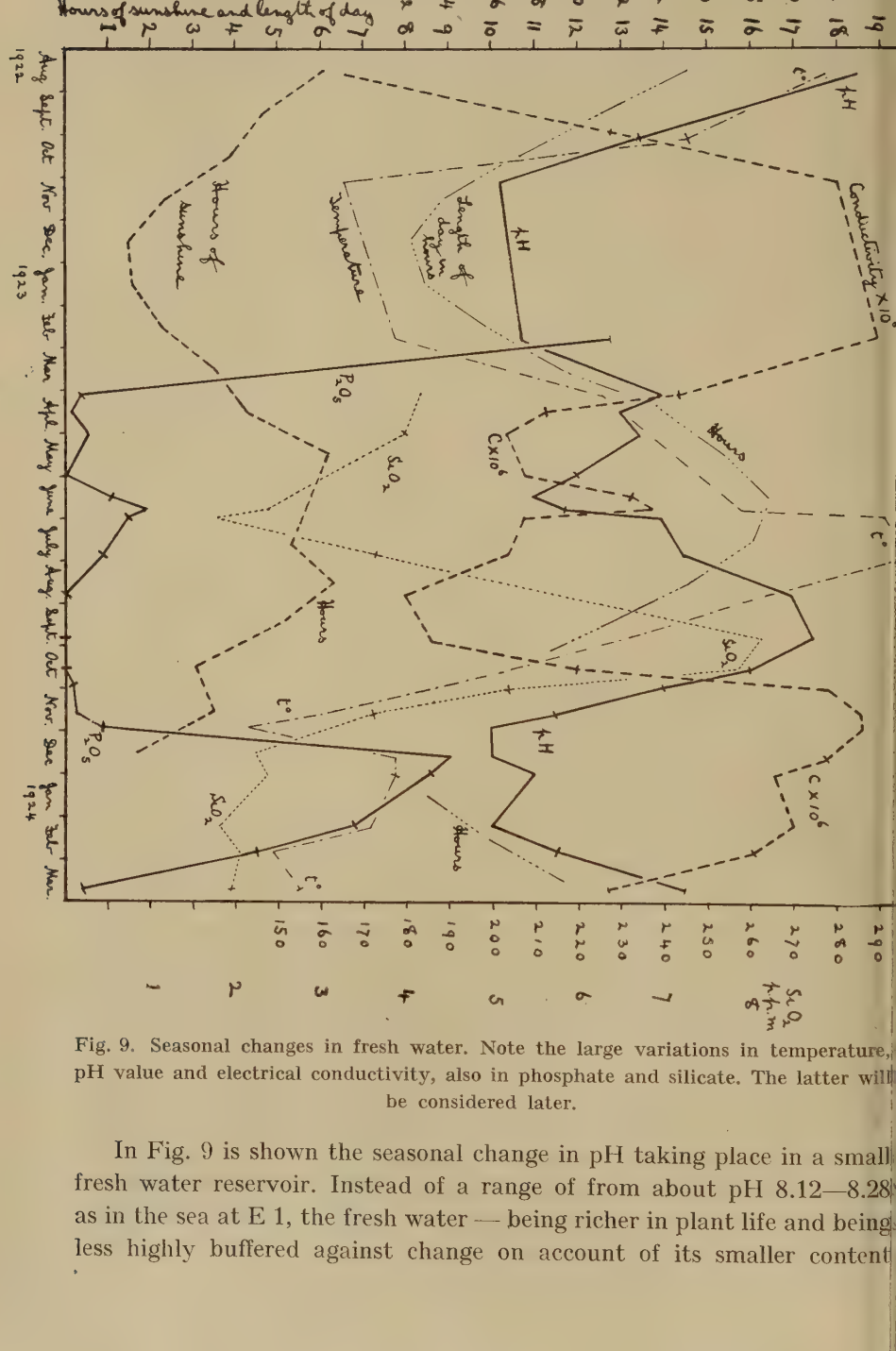


Fig. 9. Seasonal changes in fresh water. Note the large variations in temperature, pH value and electrical conductivity, also in phosphate and silicate. The latter will be considered later.

In Fig. 9 is shown the seasonal change in pH taking place in a small fresh water reservoir. Instead of a range of from about pH 8.12—8.28 as in the sea at E 1, the fresh water — being richer in plant life and being less highly buffered against change on account of its smaller content

of magnesium bicarbonate — varied from about pH 7.6 in winter to 9.3 in summer, with a secondary maximum in spring. Fig. 9 also records the seasonal changes in the electrical conductivity of the water. These are large and vary inversely as the pH values, because apparently the conductivity is mainly due to bicarbonates. As photosynthesis abstracts carbon dioxide the latter are progressively converted into the less soluble carbonates and precipitated. Other salts are also used up when plant growth is active, hence the conductivity falls. In sea water the smaller pH range and the vastly larger quantities of chlorides and sulphates render the conductivity change inconspicuous.

It has been noted that in the sea water the pH range is relatively small. This, however, is because it is sparsely populated. In a jar *Ulva latissima* was observed to bring the alkalinity up to pH 9.7 when in direct sunlight and a pure culture of the diatom *Nitzschia closterium* W.SM., in a good north light became progressively more alkaline, so that starting at pH 8.2 when the culture was young it eventually reached pH 9.4.

Up to this, alteration in pH has only been reviewed in so far as it concerns the relatively shallow water of the English Channel. Palitzsch (1911, 1912) obtained the results given in table 8, which deal with deep water; those for the Faroe Is. were determined in May and June, and the Mediterranean values between June and September. Palitzsch also looked for a relation between increase in alkalinity and in oxygen content of the water. In general a region of high pH value is also high in oxygen, as a natural result of photosynthetic activity. Low pH values are found in regions where oxygen is reduced in amount, or even absent, as in the Black Sea and the lower strata of certain fresh water lakes in which a well marked epilimnion has long persisted. Oxygen is usually present in the upper 100 metres of the open sea to an extent not far from saturation and as its lack never hinders the growth of the phytoplankton it will not be further considered here. Gaarder (1917) and Helland-Hansen (1914) studied the relation between the pH value and oxygen saturation the latter working notably in the open Atlantic. Gaarder's figures for C_{OH} and O_2 in Inderopollen bring out the relation clearly.

Inspection of the table makes it clear that the deeper water, far removed from photosynthetic action and subject to relatively little vertical mixing, is a region in which carbon dioxide accumulates in excess of the partial pressure at which it is in equilibrium with its own content in the air. The accumulation appears to be due to the decomposition of animal and plant remains which also enrich the deeper waters

Table 8.

Depth in metres	N. Sea, E. of Faroe Is. pH	Atlantic W. of Portugal pH	Mediterranean between Sardinia and Italy pH	Black Sea
0	8.13	8.22	8.23	8.34
100	8.09	8.13	8.21	7.86
400	8.03	8.04	8.19	7.53[1]
1,000	7.98[2]	8.01	8.14	7.26
2,000	—	7.95	8.09	—
3,200	—	—	8.07	—

with phosphates and nitrates as shown in Table 9 (Atkins and Harvey 1925). The silicate content too increases with depth. The analyses were made upon water, obtained between Lisbon and the Canary Is. by Dr. Kemp in the R. R. S. "Discovery", which was examined in Plymouth slightly over a fortnight later. The bright sunshine and high water temperature of this region combine to give remarkably high pH values down to 75 m. The agreement of the 1000 and 2000 m. values in this series and in Palitzsch's off Portugal is striking, the readings being pH 8.03 and 7.94 for ours and pH 8.01 and 7.95 for his samples.

Table 9. Analyses of water from 37°44′ N., 13°21′ W., taken Oct. 12th, 1925, save the last taken Oct. 16th at 29°59′ N., 15°03′ W.

Depth in metres	t° C.	pH	In mg. per m³		
			Phosphate as P_2O_5	Nitrate as N_2	Silicate as SiO_2
0	21.10	8.35	0	15; 11	
10	21.10	—	—	7	
20	21.00	—	—	6	
30	21.00	—	—	—	220
40	21.00	—	—	16	
50	20.01	8.35	0	ca. 6	
75	17.31	8.31	5	6	
100	15.10	8.18	8	55	220
150	15.06	8.16	10	65	
200	13.86	8.11	22	100	
300	12.25	8.12	44	178; 158	250
500	10.94	8.00	50	200	280
1,000	9.55	8.03	74	264; 262; 274	450
2,000	4.81	7.94	78	ca. 265	480
3,000	3.10	7.87	88	ca. 265	1,200

[1]) H_2S below 180 m. [2]) 700 m.

The foregoing examples must suffice to illustrate the magnitudes of the pH values met with in sea water. The writer has summarised previous work (1922, 1) and LEGENDRE's comprehensive monograph (1925) is also available. It must be mentioned, however, that quantitative determinations of the carbon assimilation of the phytoplankton — and so an estimate of the total crop per unit area — can be made by means of pH measurements as is illustrated by the calculation below. For this it is necessary to ascertain the change in pH produced by the addition of an acid, preferably in $N/_{100}$ concentration, in varying amounts, and to note the equivalent quantity of carbon dioxide required to produce the change. Having once constructed this curve the quantities of carbon dioxide concerned in an alteration of say pH 8.14 to 8.20 can be read off. The result can of course be obtained simply, though less accurately by titrating the sea water using phenol-phthalein as indicator and noting the difference between the winter and spring or summer values. MOORE, PRIDEAUX and HERDMAN (1915) at Port Erin found such seasonal differences in titrating the water of the Irish Sea. Similar differences in fresh water had already been recorded by BIRGE and JUDAY (1911) and by CHAMBERS (1912), but it remained for MOORE and his co-workers to base a calculation of the annual crop upon the results. They assumed that the changes observed at the surface extended to 100 m. owing to mixing and arrived at an estimate of two tons dry weight or ten tons of moist plant per acre. Since the surface alkalinity is always reduced by mixing with the deeper water this result is rather too high.

A large number of titrations were made (1922, 1) during 1921 of the seasonal variations in alkalinity at and around Station E 1 and at E 2, these when averaged afforded the value 1.0 c.c. of $N/_{100}$ H_2SO_4 per 100 c.c. of water, which corresponds to 4.4 mg. per litre of carbon dioxide or to 1.2 mg. expressed as carbon. Since a sugar such as dextrose contains 40 per cent of this element, the amount suffices to provide 3 mg. per litre of dextrose, or slightly more than that amount of starch. This is equivalent to 3 grams of dextrose per cubic metre.

Taking the depth of the English Channel around E 2 as 83.3 m., which is very approximately correct, the carbohydrate expressed as dextrose synthesised in the column of water with a base of four square metres is one kilogram. Over an area of one square kilometre this amounts to 250 metric tons.

Were photosynthesis to remain uniform and respiration in abeyance it is obvious that there would be a vast accumulation of carbohydrate in the sea. As it is the amount present is an equilibrium between the

production due to photosynthesis and the destruction by plant and animal respiration.

The conditions in nature are regulated by illumination and by the amounts of the necessary salts which are available. On considering BLACKMAN'S work on limiting factors and the quantitative results obtained by Miss MATTHAEI (1905), it is seen that an increase of temperature may effect a very decided increase in the rate of photosynthesis. If, however, the light intensity is low, a point is reached beyond which a further temperature rise, even when not injurious, is unaccompanied by any rise in assimilation. The amount of light energy then available is insufficient to decompose carbon dioxide at a rate in excess of that already attained at the lower temperature. From the results obtained, when light was not the limiting factor, KANITZ (1915) has shown that the van't Hoff rule holds approximately, the ratio being 2.40 per 10° C. rise from 0°—10° and 2.12 from 10°—20°. For respiration similar coefficients are given so it is only when light is a limiting factor that increase of temperature is unattended by increase in photosynthesis as well as in respiration, provided injurious extremes are avoided.

Since alteration in temperature affects the bicarbonate equilibrium, a rise tending to increase the alkalinity, the value 1.0 c.c. of $N/_{100}$ H_2SO_4 as determined by titration is subject to a correction. It appears that the correction cannot exceed 0.3 c.c. under the conditions studied. This would reduce the estimated crop by 30 per cent. The pH range for E 1 was observed to be 0.13, or corrected for the part possibly due to the establishment of a temperature change equilibrium, the range is pH 0.10. It is doubtful, however, that equilibrium is ever reached, especially when KROGH'S determinations of the rate of exchange of CO_2 between air and sea water are borne in mind. The range found, pH 0.10, corresponds to 1.0 c.c. of acid very approximately, so the figure 250 metric tons per square kilometre may stand as an approximate value for the carbohydrate photosynthesised.

The phosphate content of natural waters as a factor limiting the production of phytoplankton.

A brief mention has already been made of the amounts of phosphate nitrate and silicate in sea-water, data concerning which have been presented in Table 9. These analyses of deep Atlantic water, made quite recently afford information that has long been wanted and may be discussed here before the earlier work has been considered.

Inspection of the table shows clearly that all three are present in

minute amount; only in the deepest water is the most abundant — silicate — in excess of one part per million. The analyses are expressed in milligrams per cubic metre, which for fresh water would be in parts per thousand million; for salt water the latter number would require to be somewhat raised on account of its greater density. It is noticeable moreover that all phosphate has been removed from the surface water

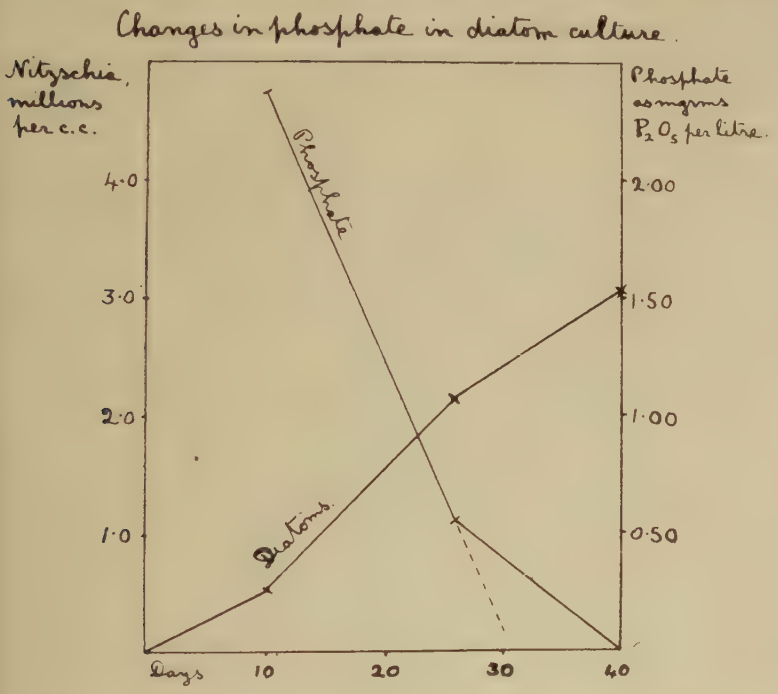


Fig. 10.

and but little nitrate has been left. The silicate, though much reduced, is still present in relatively greater amount. The indication is that the phytoplankton is responsible for the removal of these nutrient salts. Fig. 10 illustrates the change in phosphate as the diatom *Nitzschia closterium* multiplies in sea water enriched with MIQUEL's solution. It was found that 1×10^9 diatoms used up 1.12 mg. of phosphate, reckoned as P_2O_5, accordingly one gram should suffice for 9×10^{11} *Nitzschias*. Data which will be presented later give 30 mg. per m^3 for the annual consumption of phosphate in the water at E 1, taking the average of 70 m., surface to bottom. From this it follows that if all this phosphate were abstracted by diatoms each cubic metre of sea water would produce 26.8×10^9 diatoms. As many as 30×10^9 of another

species of diatom were found by the writer in a fresh water pond, so these large numbers, as calculated, need not seem impossible. Nothing approaching such a number of diatoms is, however, present in the sea simultaneously, and the figure for plankton organisms in summer found by ALLEN (1919) using the cultural method amounts only to 464×10^6 per m^3, or 0.464×10^9, about one sixtieth of the number calculated as possible. In view, however, of the differences in the size of the various organisms and of the fact that the zooplankton, many of which are of relatively enormous mass, consumes the phytoplankton, the agreement between the estimate and the measurement is as close as could be expected.

It is of interest to consider what volume of water is stripped of its phosphate by one diatom, for since the diatom floats freely in the water it can only draw on a relatively limited water volume. Assuming that the water contains 30 mg. per m^3 of phosphate, as it does early in the spring, and making use of the result of the experiment shown in Fig. 10, that one gram of phosphate, reckoned as P_2O_5 suffices for 9×10^{11} *Nitzschias*, it is found that each diatom has only to strip one twenty seventh part, viz 0.037, of a cubic millimetre of water. In other words there may be 27 diatoms per cubic millimetre; as found before the value was 26.8, merely due to a rounding off in the evaluation of the constant. At the limit of what can be detected, 1 mg. per m^3, each diatom has to strip over one cubic millimetre in order to get enough phosphate, consequently the greater the dilution the slower must be the rate at which further diminution in phosphate proceeds.

The earlier analyses of the phosphate content of sea water have been reviewed by MATTHEWS (1916), RABEN (1920), and BRANDT (1920); they are all vitiated by analytical imperfections. With samples taken just outside Plymouth Breakwater MATTHEWS found a maximum of 60 mg. per m^3 at the end of December, 1915, with an irregular fall to a minimum of less than 10 mg. per m^3 in April and May. He attributes the seasonal variation to the removal of phosphates from solution by the fixed algae, the diatoms and *Phaeocystis*, a unicellular and primitive brown alga which occurs in these waters very abundantly in late spring. The minute quantity of phosphate in sea water may be realized when it is mentioned that, using the purest chemicals, MATTHEWS was unable to prepare artificial sea water containing less than 28.6 mg. per $m.^3$, which is only a little less than the winter maximum value at E 1.

RABEN's analyses extend from 1904—14, and include numerous determinations upon the water of the North Sea, Baltic, Barentz Sea and North Atlantic Gulf stream. These, as plotted by Brandt, show

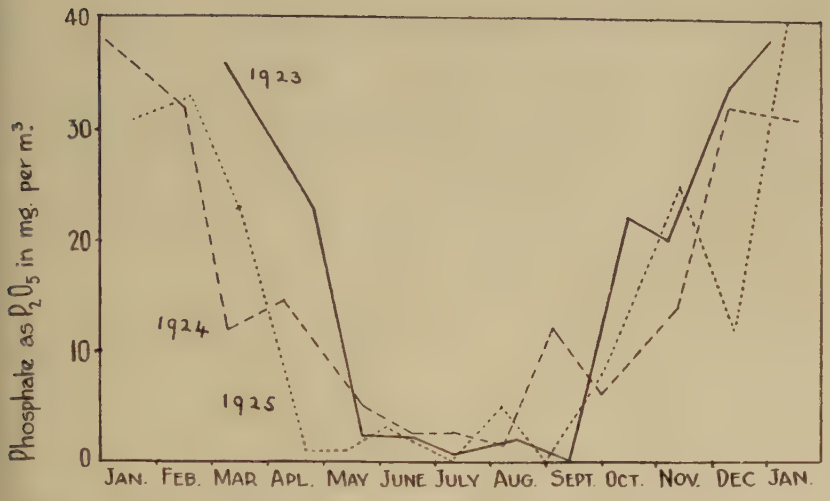


Fig. 11. Seasonal changes in phosphate concentration at Station E 1, surface.

minimal values in May and June. After a rise to a peak in September low values are again shown early in October. BRANDT's graph, like that given by MATTHEWS, refers to surface water, though RABEN also analysed water down to 800 m. in the N. Atlantic. There is usually a considerable increase from surface downwards. None of the values, however, indicate exhaustion of the water as regards phosphate, the minimum recorded figure being 51 mg. of P_2O_5 per m^3 and the maximum 221 mg., both being from North Sea Station N 7. These figures are about four times as great as those given by MATTHEWS, whose results

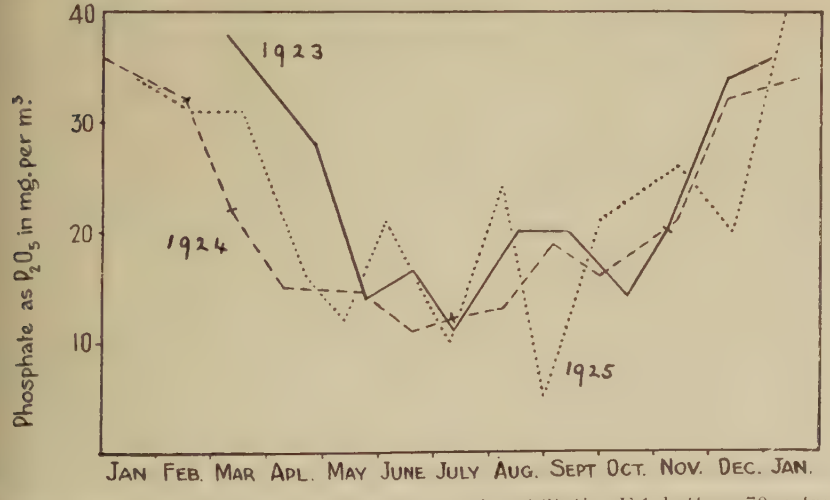


Fig. 12. Seasonal changes in phosphate concentration at Station E 1, bottom, 70 metres.

agree well with those of the Government Chemist, London, who also used POUGET and CHOUCHAK's method (1909, 1911). The analyses carried out by the writer according to DENIGÈS' method (1921), which is entirely different, are in close accord with MATTHEWS' results. Owing to an analytical error, the source of which will, it is hoped, be pointed out

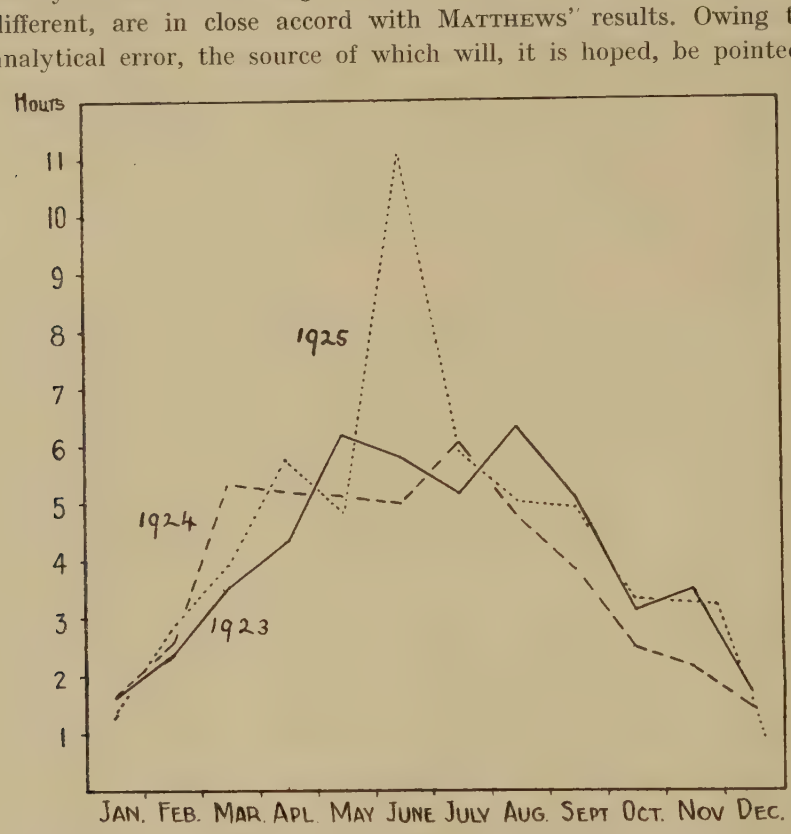
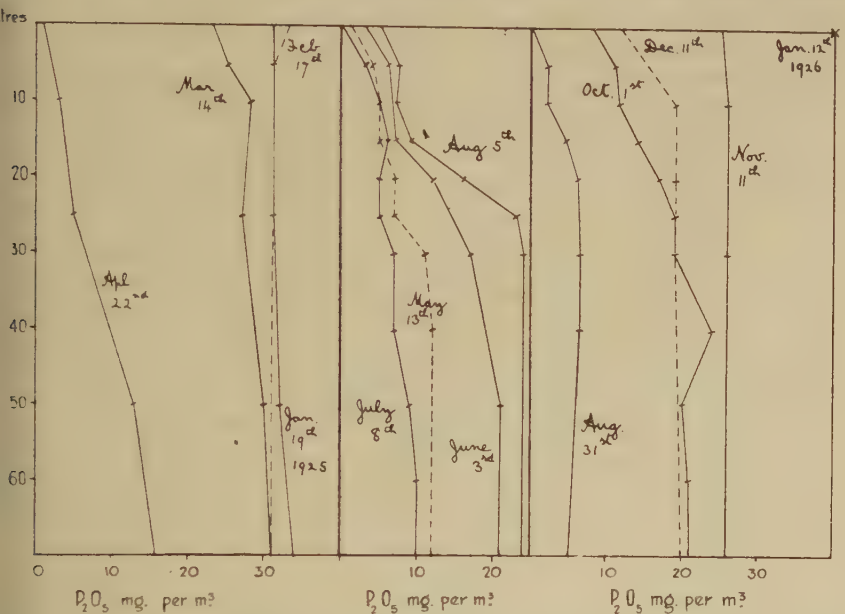


Fig. 13. Mean monthly sunshine records for England S.W. (including Wales), plotted for 15th of each month. Note the high values for spring sunshine in 1924.

elsewhere, RABEN's values are all too high and so mask the fact that phosphate is at times completely used up in surface water and accordingly becomes the factor which, under these conditions, limits the development of the phytoplankton.

A study of the seasonal changes at Station E 1 may be advanced in support of the foregoing. Figs. 11 and 12 show how the phosphate varied in the surface and bottom (70 m.) water respectively during the years 1923, 1924 and 1925. The curves are qualitatively very similar, but show notable quantitative differences. Of these the most striking are that in both figures the times, at which the vernal decrease in phosphate becomes manifest, are markedly different, 1924 being about two months

arlier than 1923, with 1925 occupying an intermediate position. Inspec-
ion of Fig. 13 gives the answer to the problem raised by these differences,
or in 1924 the early spring was characterised by much sunshine, whereas
n 1923 as high values were not obtained till two months later, 1925
eing again in a mean position. Once the phosphate near the surface,
nd so in an adequately illuminated region was all used up, a further
ncrease in illumination could obviously have no further effect there.



ig. 14. Variation of phosphate concentration with depth at Station E 1 during
925. For the sake of clearness the curves for the months have been plotted in three
sections.

t greater depths an increase in intensity and in duration of illumination
esult in a depletion in phosphate, similar to that near the surface;
his may naturally be looked for later in the year. Beyond a certain depth,
owever, which varies with the surface illumination and the efficiency
ith which it is transmitted, down-grade processes predominate and
hosphate is regenerated. Hence the sharp peaks in the mid-summer
ortion of Fig. 12. These do not occur earlier in the year, for then the
ertical circulation of the water due to the action of waves, wind and
the residual effect of surface cooling, is bringing up fresh supplies
ntinuously. But when the warm upper layer or epithalassa is once
tablished vertical communication is greatly diminished. A study of
e temperature differences over the periods during which regeneration

of phosphate became marked shows clearly that little or no mixing of surface and bottom water could have taken place. Fig. 14 constitutes a record of the phosphate concentration at E 1 during 1925, the year

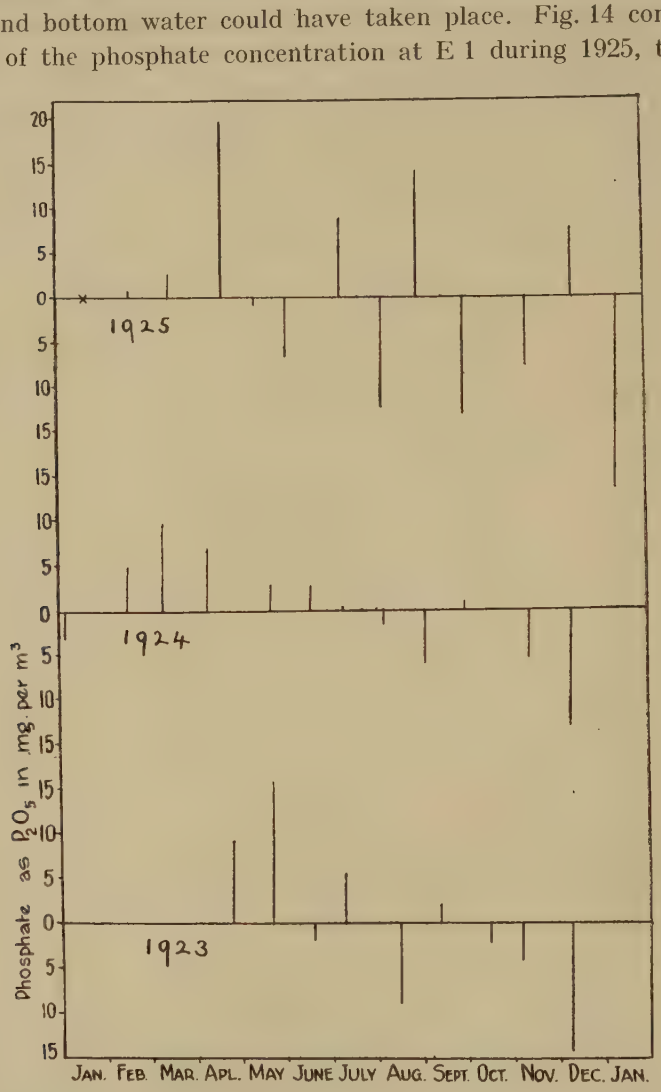


Fig. 15. The production of phytoplankton may be deduced from the uprights abov the zero line; in reality these lines show the difference in the phosphate content the water between two successive observations. Increase in phosphate, being equivale to destruction of phytoplankton is represented below the zero line.

being divided into three periods, of four months each, for the sake clearness. The shifting of a curve to the left denotes decrease, to the rig increase. Use has been made of data of Fig. 14 to ascertain the averag phosphate concentration in the water column of 70 metres. Since th

hosphate is used up in producing the phytoplankton the amount of ıch increase over any period may be taken as the difference between ıe initial and final concentrations. Such differences are shown in Fig. 15, ıose above the zero line representing outbursts of plant growth, those be- ›w representing regeneration of phosphate. These represent, however, the ebit or credit balances, noted at intervals, of a current account. The ›ecies dominant at one period may later be replaced by another, though consumption and regeneration balanced no indication of any such ıange would have been given. Fig. 15 serves, however, to help us to ace the major changes taking place in the phytoplankton. Thus con- dered it is seen that 1924 was characterised by an orderly sequence, ith evidence of only a slight autumnal outburst; but it must be pointed ut that this may have occurred in the six-weeks gap in the observations om Oct. 1st to mid November.[1]) 1923 and 1925 are similar in being ıaracterised by notable outbursts of growth, those in July, late August nd December being remarkable, especially the last, which was accom- anied by the development of a *Rhizosolenia robusta* maximum, other ıembers of the species being also present at this very unusual period f the year. In making the foregoing deductions it has been assumed ıat there have been no considerable water movements such as to upset ıe validity of the phosphate cycle. The salinity data for the period egative the suggestion of extensive water movements, save in so far s concerns the winter of 1925 for which no salinity data are as yet vailable.

By subtracting the consecutive values for the mean phosphate content the water column at E 1 it is possible to arrive at an annual balance ıeet, as shown in Table 10. In constructing this the maximum value ven for the winter is held to include the early January result of the llowing year if this is greater than the December value.

It should be added that during the mid-winter period the sea is rela- vely poor in phytoplankton around the British Isles, hence the phyto- ankton crop calculated from the phosphate changes is an approach a full measure, though always somewhat too low.

From Table 10 it may be deduced that the phosphate cycle at E 1 as a closed system during the years studied. It is possible, however, ıat periods of influx of water may either increase or decrease the phos- ıate content at E 1. For example, from the incomplete data available

[1]) Owing to weather conditions and other demands on the boat it has not always been possible to make observations at regular or desirable intervals. Furthermore it is only of late that it has been borne in upon the writer how great may be the changes in phosphate concentration taking place in a relatively short time.

Table 10. Phosphate balance sheet from March 1923 to January 1926 inclusive, shown as milligrams of P_2O_5 per m^3, for the 70 m. water column at E 1.

Year	1923	1924	1925	1923—25
Total observable consumption . . .	33.4	29.5	53.8	—
Maximum minus minimum	29.6	28.3	26.9	—
Total observable regeneration . . .	33.4	24.5	61.7	—
Gain in free phosphate, difference of successive maxima	— 3.0	— 5.0	+ 8.0	0.0
Gain in free phosphate, consumption minus regeneration	0.0	— 5.0	+ 7.9	+ 2.9

for the region of the Faroe-Shetland Channel it appears that the water there was considerably richer in phosphate during the summer of 1925 than it was during 1924. Quite in keeping with this was the observed increase of the phosphate content of the North Sea water in May 1925 as compared with roughly the same season in 1924. This is suggestive of the possibility of the entry of richer water, from the unilluminated depths of the Atlantic, into the North Sea via the North of Scotland. No conclusion can be based upon the data now available, which are, however, entirely favourable to this hypothesis.

Analyses made of water from the Mediterranean and between England and S. America show that the surface water of these sunny regions is almost or altogether stripped of phosphate. The deep water, as recorded in Table 9 is rich. Owing, however, to the fact that no great cooling occurs in winter, vertical mixing proceeds to lesser depths the further one moves towards the equator. Near it, however, there is evidence of some upwelling of deep water which replaces that driven polewards by the trade winds. In fact as the range of the annual temperature variation becomes reduced, so also is that of the phosphate cycle. Furthermore since dead organisms sink as they finally disintegrate and since the ocean waters are very deep it is obvious that the bottom water — or the water sufficiently deep to become really rich in phosphate — will not enter into the vertical circulation at all. Thus a lesser phytoplankton might be expected as the temperate zones are left, which is precisely what is found as may be seen from LOHMANN's (1920) results. JESPERSEN's (1924) graph for the Atlantic macroplankton also brings out clearly how much richer the coastal zones are than the open ocean where the stratification of the water is not disturbed by the effects due to proximity to land or to shallow water areas.

The richness of northern waters may accordingly be considered as due to the better vertical circulation as regards the temperate zone; also to the fact, which becomes more marked in high latitudes, that since light is the limiting factor for plant growth for a considerable portion of the year, the water accumulates a greater store of phosphate. Then when daylight returns, or lengthens its duration, a great outburst of the phytoplankton takes place.

Two further deductions may be made from a study of the phosphate cycle. It has been shown that a measure of the time and magnitude of the spring outburst of phytoplankton is given by analyses of the phosphate content of the water; this renewal of activity has been found to be dependent upon the quantity of light available rather than upon the temperature of the water. Animals, however, are regulated as regards reproduction and growth rather by temperature than by light. From this it follows that the hatching out of the young of various species which are dependent, directly or indirectly, upon the vernal outburst of the phytoplankton may take place before an adequate supply of the latter has become available and there are obviously many gradations between times of famine and of plenty. Thus this suggestion as to seasonal variations in the zooplankton, which has long been current, receives an added measure of support.

Again a knowledge of the phosphate consumption enables an estimate to be made of the minor limit of the annual phytoplankton crop. The limit is minor if based upon the figure "maximum minus minimum" in Table 10. If based on the "total observable consumption" results in this table it will still be too low, for this is only a balance figure as already explained. Taking the consumption as 30 mg. per m^3 to a depth of 70 m. at E 1 and that the phosphate content of the plankton is 0.15 per cent., calculated on the wet weight, as for the brown algae, it results that the column of water produces 1.4 kilograms of phytoplankton. If it be assumed that the carbon content of the algae, reckoned as a hexose sugar, amounts to 15 per cent. of the wet weight the calculation previously given, based on the seasonal change in alkalinity, gives an identical value 1.4 kg., when recalculated for 70 m. depth instead of 83.3 m. The exact agreement is fortuitous, but it lends support to the validity of the titration method, which is less exact than is the phosphate estimation. Thus the minimum value for the crop is 1,400 metric tons, wet weight, per annum, per square kilometre.

Fig. 9 shows, among other things, how the phosphate content of the water of a small reservoir undergoes seasonal changes so that its winter value, which is high owing to the drainage from the surface of pastures

stocked with cows, rapidly falls in spring. Similar results were obtained in a quarry pond, and the phenomenon appears to be perfectly general in all fresh waters.

The silicate content of natural waters.

In Fig. 9 is also shown the changes in the silicate content of the small reservoir. The total range is from about 2 mg. of silicate, estimated as SiO_2 per litre, up to 8 mg. — or 2000 to 8000 mg. per m^3, quantities vastly greater than the phosphate content. The sequence of the changes is hard to interpret since matters are complicated by surface drainage, but some slight portion of the decrease, and a larger proportion in another pond, appears to have been occasioned by the removal of the silicate by diatoms to form the siliceous valves

Brandt (1920) has recorded a seasonal change in the Baltic, silicate as silica varying from 900 mg. per m^3 in February to 600 in May, followed

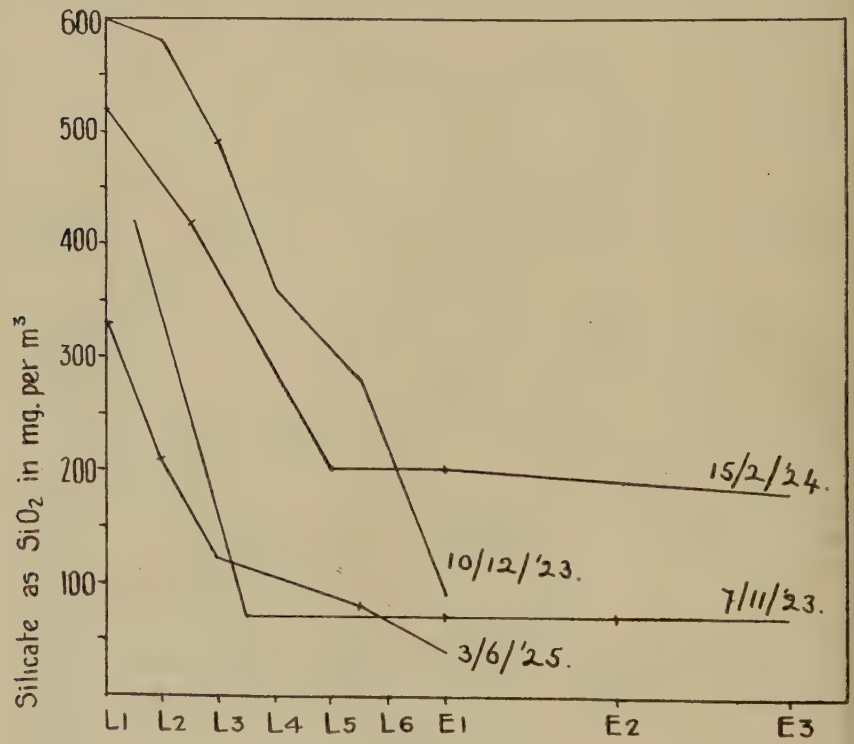


Fig. 16. Decrease of silicate from Plymouth Sound to open sea of English Channel. The L stations are at approximately equal distances apart and E 2 is midway between E 1 and E 3, which is off Ushant, but the distances are not shown to scale, that between the E stations being relatively much reduced.

by a rise in June. Bottom water in February contained 1150 mg. As the Baltic receives large accessions of fresh water and is land-locked, it is to be expected that its water should be richer in silicate than is the English Channel and the Atlantic. Table 9 shows that only at great depths in the Atlantic is water found which is as rich as is the shallow water of the Baltic. This indicates that the surface water of the Atlantic

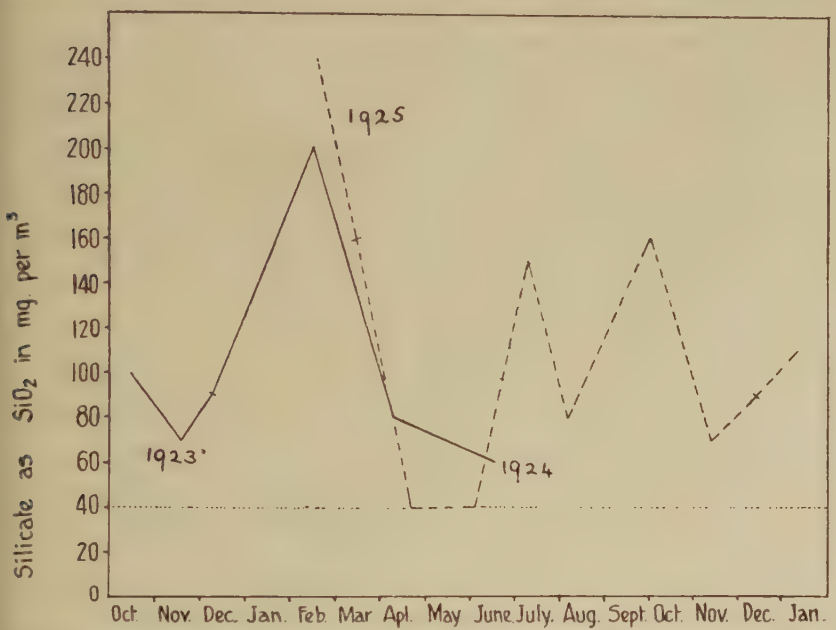


Fig. 17. Seasonal variation in silicate at Station E 1, surface. The dotted horizontal line at 40 mg. per m^3 denotes the limiting amount of silica detectable. A value of 40 mg. may therefore be any lesser amount.

is poorer in silica because the latter has been depleted by the development of diatoms. It should be added that the silica values recorded in Table 9 may be somewhat high owing to the action of the alkaline sea water upon the glass. The error is negligible in freshly drawn water from the colder English Channel and is probably not serious for the figures mentioned previously; though lower values were obtained from similar Atlantic water in winter, when the solvent action would have been less, there was no indication of the silica content limiting diatom production in the open ocean.

The difference in the silicate content of Plymouth Sound and of the coastal waters as compared with the true Channel water is shown in Fig. 16 and in Fig. 17 the seasonal variations at E 1 have been plotted. Fig. 18 has been constructed for silicate precisely as Fig. 15 was for

phosphate. Over the limited period Jan. 1925 to Jan. 1926 inclusive the analyses denote a depletion of silica to the extent of 130 mg. per m³. The curve for 1925 in Fig. 17 makes it evident that it is possible that during April and May the silicate was all used up and so, equally with the phosphate, may have set a limit to the production of one class of

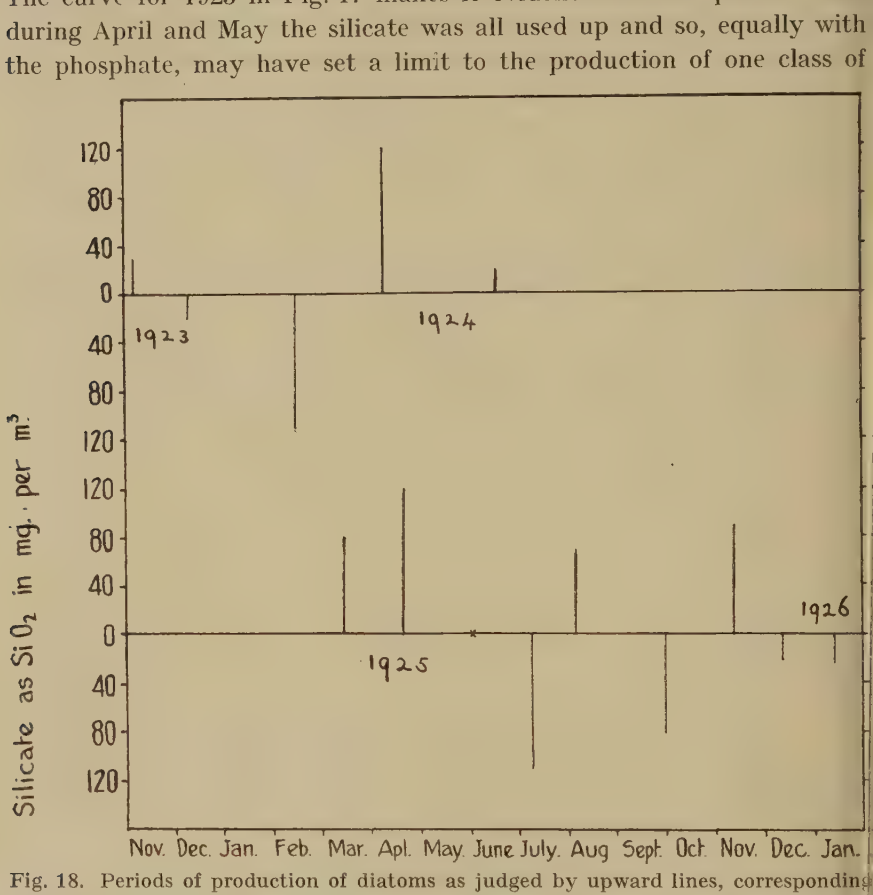


Fig. 18. Periods of production of diatoms as judged by upward lines, corresponding to mg. per m³ of silicate, as silica, used up. Downward lines denote enrichment in silicate, due to its regeneration from the decay of diatoms or from other sources

the phytoplankton, to wit the diatoms. This is suggested because 40 mg. per m³ is the limit of silica detectable, accordingly this amount may signify any lesser quantity; a dotted line has accordingly been drawn at this level. Above this amount increments of 20 or even of 10 mg. per m³ are measurable. The limit ascertainable, 40 mg. per m³ would however, be the winter maximum for phosphate.

The nitrogen compounds of natural waters.

The nitrogen compounds present in water have been subjected to much attention, but on account of the analytical difficulties attending

such work, more especially as regards sea-water, the number of workers who have obtained more than a few results is small.

Firstly we are in ignorance as to the source of these compounds, save in so far as they are derived from the land. Evidence pointing to the fixation of gaseous nitrogen by the higher plants has been brought forward by a number of workers, whose cultures were, however, not free from bacterial contamination. Of these WANN (1921) is noteworthy for the care he exercised and the multiplicity of his experiments. Working with pure cultures of unicellular fresh-water algae, he found that fixation only took place when the culture had been supplied with nitrate and glucose. SCHRAMM (1914) had previously experimented with a number of species and demonstrated that in the absence of added nitrogen compounds no fixation took place, accordingly WANN included a little nitrate. BRISTOL and PAGE (1923), however, showed that WANN's analytical procedure involved a loss of nitrogen at a certain stage, and the more nitrate present the greater was the loss. Consequently when the algae had used up much of the nitrate the loss was reduced and so as compared with the control a gain was indicated. Their own cultures showed no gain and were a complete vindication of SCHRAMM's conclusion in support of the views held since the early work of LAWES and GILBERT. Bacteria in the gelatinous sheathing in which algae are encased may perhaps be responsible for some such fixation.

JUDAY (1925) and his co-workers have recently made a detailed qualitative and quantitative investigation of the nitrogen compounds in the waters of Wisconsin lakes. A few analyses by DREW (1914) of the water of ponds and their vernal changes are also extant.

The Wisconsin lakes were proved to contain the following quantities as shown in Table 11.

For these analyses large volumes of water were evaporated down to small bulk, a procedure which is not possible in the case of sea-water. It will be noticed that the intermediate break-down products of living matter predominate over the final stage, nitrate. Furthermore even in summer the nitrate nitrogen remaining in the lake water is not very greatly less than the plankton nitrogen. There is a complete absence of any evidence that in the water of these lakes a deficiency of nitrogen acts as a factor limiting the plankton. The total soluble nitrogen, organic nitrogen, inorganic nitrogen and plankton nitrogen were determined for the surface and bottom water of Lake Mendota from June 1922 till May 1924. Throughout this period the surface plankton nitrogen was far less than the organic nitrogen — about one fourth — and save in June and July 1922 it was less than the inorganic. It must be remembered

Table 11. Forms of nitrogen in Lake Mendota water, in mg. per m³.

No.		Surface June 18, 1924		Bottom [1]) June 25, 1924	
I	Plankton [2])	—	92.4	—	44.9
II	Soluble nitrogen	—	515.6	—	766.9
	1. Free saline ammonia nitrogen	96.0	—	280.0	—
	2. Residual saline ammonia nitrogen	16.0	—	20.0	—
	3. Nitrite nitrogen	10.0	—	17.0	—
	4. Nitrate nitrogen	69.4	—	92.6	—
	5. Free amino nitrogen	54.0	—	81.0	—
	6. Peptide nitrogen	135.0	—	140.4	—
	7. $^1/_2$ of tryptophane nitrogen	5.3	—	7.0	—
	8. $^2/_3$ of histidine nitrogen	3.8	—	6.8	—
	9. $^3/_4$ of arginine nitrogen	31.1	—	34.7	—
	10. Amide nitrogen	12.4	—	19.3	—
	11. Purine nitrogen	8.4	—	9.5	—
	12. Amine nitrogen	14.2	—	16.0	—
III	Forms of soluble nitrogen determined, total	—	455.6	—	724.3
IV	Undetermined nitrogen	—	60.0	—	41.9

though that the plankton as thus obtained from water pumped up will have included only the smaller members of the zooplankton. It was found that all forms of nitrogen (save that in plankton) reached a maximum in the winter and a minimum during summer.

The methods applicable sea water have been worked out by Raben (see Brandt 1920) and similar or other methods have been studied by Witting (1914), Buch (1915, 1923), Gad-Andresen (1923) and Alsterberg (1924). The elaborate researches of Brandt, Raben and their co-workers have given us almost the whole of our knowledge of the saline and albumenoid ammonia of sea water and its seasonal changes, accompanied by analyses of nitrate and nitrite.

The estimation of nitrite in sea water may be performed colorimetrically by means of the Griess-Ilosvay reagent as pointed out by Buch (1923) and Harvey (1926). Orr (1926) gives analyses made by this method upon water in the Clyde Estuary and adjacent channels. Nitrite

[1]) The bottom sample was pumped up from 20 metres below the surface where the lake is about 23 metres deep.

[2]) As determined by use of a Sharples centrifuge at a speed of about 40,000 R.P.M.; water flowed at rate of one litre per three minutes.

was found to be present in minute but measurable amounts, which were always greater near the bottom than at the surface.

Previous estimations of nitrate in sea water had been carried out by reducing it to ammonia and either treating with NESSLER solution as usual or estimating the nitrogen evolved (GAD-ANDRESEN 1923). HARVEY, however, made use of DENIGÈS (1910) qualitative test with reduced strychnine and proved that it was capable of giving quantitative results when the colour given by each batch of the reagent is compared with a standard. Numerous analyses were made by this means both of the water of the English Channel and from the depths of the Atlantic, mercuric chloride being used as a preservative. Table 9 has already shown how rich in nitrate are the dark depths of the ocean. The upper 50 metres are greatly depleted and average slightly under 10 mg. of nitrate nitrogen per m^3, the phosphate, however, has been completely used up within this layer of water. Very similar results were obtained in the water off Norway and in the Faroe-Shetland Channel, save that in these northern waters neither nitrate nor phosphate had been entirely removed.

Thus, just as was found for phosphate, the deep ocean water acts as a reservoir of nitrate, which is regenerated at or near the bottom both in the ocean and in shallower seas. Table 12 records the condition at the three stations E 1, 22 miles from Plymouth Hoe on the course to Ushant, E 2 in mid-channel and E 3 off Ushant.

Table 12. Nitrate content as N_2 in mg. per m^3, during 1925.

m.	May 13th			July 8th			Dec. 11th & 15th	
	E 1	E 2	E 3	E 1	E 2	E 3	E 1	E 2
0	2	—	67	4	3[1])	40[1])	38	—
10	3	55	85	—	—	—	40	106
20	5	—	85	4	24[2])	40[2])	43[2])	120[2])
30	2	53	67	—	—	—	—	—
50	9	15	67	—	29	40	48	120
70	8	—	—	4	—	—	43	—
90	*	29	—	*	29	—	*	132
105	*	*	67	*	*	40	*	*

The seasonal changes in nitrate at Station E 1 are shown in Fig. 19 and their similarity to those in which phosphate is concerned (Figs. 11

[1]) 5 metres value. [2]) 25 metres value.

and 12) is at once evident. In the open sea then phosphate and nitrate are both completely used up by the phytoplankton, though a closer comparison of the results shows that sometimes one and sometimes the other appears to be the limiting factor. Too much stress cannot, however, be laid upon small differences in figures representing, very approximately, parts per thousand million. In Table 13 the data for both salts have

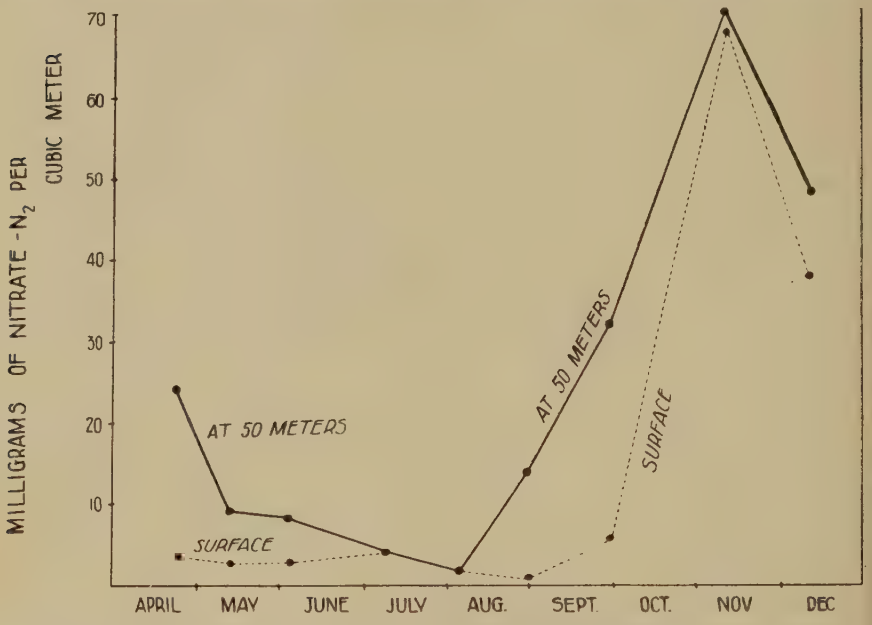


Fig. 19. Nitrate content of sea water at Station E 1, 22 miles S.W. of Plymouth, during 1925 in the surface 5 metres and at 50 metres.

been arranged so that a comparison may be made of the conditions prevailing at such periods. It should, however, be added that owing to the differences between successive batches of the reagent and the shorter column of liquid examined the accuracy obtainable in the nitrate estimations is possibly less than in those of the phosphate.

A study of Table 13 makes it clear that, though as regards the surface water in April, May and July phosphate is less plentiful than nitrate, if we consider the upper 20 metres there is but little difference, and in June the surface values were identical. Viewing the water column as a whole one important fact makes itself evident, namely that there is a continuous decrease in nitrate up to Aug. 5th, when the whole column is almost entirely depleted. The value, however, is but little less than that of July 8th. But the phosphate has, during the period from April to August, shown marked variations, a rise on June 3rd and a greater

Table 13. Phosphate as P_2O_5, shown under P, and nitrate as N_2 under N, both in mg. per m^3, as found in sea water at Station E 1 during the spring and summer of 1925.

m.	Apl. 22nd		May 13th		June 3rd		July 8th		Aug. 5th		Aug. 31st		Oct. 1st	
	P	N	P	N	P	N	P	N	P	N	P	N	P	N
0	1	4	1	2	3	3	0	4	5	0	0	0	8	6
10	3	2	5	3	104	3	5	—	7	—	2	—	11	6
20	5	3	7	5	12	—	5	4	16	3	6	9[1]	17	21
30	—	—	11	2	17	—	7	—	24	—	6	—	19	32
50	13	24	—	9	21	8	9	4	—	3	—	14	20	32
70	16	24	12	8	21	9	10	4	24	0	5	14	21	(19)[2]

one on Aug. 5th; it thus appears that phosphate is regenerated during this portion of the year more rapidly than is nitrate, accordingly the absence of nitrate early in August allowed of a considerable accumulation. Later on, however, nitrate is regenerated more rapidly than phosphate. The probable explanation is as follows; the regeneration of phosphate is for the most part simply the splitting up of organic compounds in which the phosphate radicle is present as such, though a portion is present in more complex compounds and in the insoluble and aggregated condition of calcium phosphate in exoskeletons and bones. Nitrate production is, however, the last of a series of changes, so there is of necessity a latent period while the protoplasm is being broken up to ammonium salts, which in turn are converted into nitrates. Thus it follows that during the latent period for nitrate an accumulation of phosphate takes place, which, however, is soon overtaken by nitrate formation. This appears to be the interpretation to be placed on the figures for Aug. 31st, in which much of the regenerated nitrate has been used up in producing phytoplankton sufficient to deplete the phosphate to the lowest value found during three years. At the surface the supply of both has been exhausted. By Oct. 1st the nitrate has established a definite lead in the deeper water; this had become far greater in November, in which the concentrations were: phosphate 25, nitrate 68 mg. per m^3 in the surface water.

Harvey has further shown that ammonium salts added to surface water from E 1 give rise to no nitrate, whereas when bottom water is used the production of nitrate can be demonstrated inside less than a

[1]) 25 metres value.

[2]) Low owing to analytical error caused by reducing action of abundant organic matter.

week. If, however, *debris* from the bottom be added to E 1 surface water, it too produces nitrate — evidently because the requisite bacteria have been supplied.

Oxidation in natural waters.

The breaking down of living matter and of cellulose plant cell walls in the sea has not as yet received much attention. The total proteid may be deduced approximately from the figure for albumenoid ammonia. Brandt's (1920) determinations and a certain number carried out in the Government Chemist's Laboratory, London, are available. The latter were in connection with questions concerning oyster mortality and are for inshore waters.

An idea of the amount of respirable organic matter in sea water was obtained (1922) by noting the change produced in the pH value on storing after addition of the indicator. In spring but little alteration occurs, whereas in autumn the reverse is true. At the levels between 15 and 25 metres and again near the bottom, marked differences are observed. In the production of these the organic matter of such of the plankton as die during storage is concerned.

The pH decrease observed corresponds to the production of 1.0 to 2.5 or 3.0 c.c. of $N/_{100}$ acid per 100 c.c. of sea-water. This is equivalent to the carbonic acid produced by the complete oxidation of from 3 to 8.0 or 9.6 mg. of a hexose sugar per litre. Determinations by Raben on freshly drawn filtered sea water show an absorption of 8 mg. of oxygen per litre, as determined by the alkaline permanganate method. This corresponds to 7.5 mg. p. l. of hexose sugar. The writer (1923) has, however, found much lower values, about 1 mg. p. l. of oxygen absorbed, for water at E 1; this, however, was in March, when but little unoxidised matter is to be expected.

Oxidation in sea water has been studied by Harvey (1925) and it was proved that certain easily oxidised substances were oxidised more readily by the deeper water at E 1 than by the surface water. There are indications of the presence of a catalyst, probably an iron compound. Its action is inhibited in surface and inshore waters by dissolved organic matter. Evidence afforded by a quantitative study of the rate of destruction of hydrogen peroxide by sea water confirms the foregoing.

Conclusion.

From the foregoing survey certain facts emerge. To begin with, there are as yet many lacunae in our knowledge of algal metabolism

and its seasonal changes. For one thing, further work is required upon the ammonium compounds in sea water. It has perhaps been tacitly assumed, though quite unintentionally, that ammonium salts are not directly utilized by algae — they have in fact been regarded as a stage in the production of nitrate. That even the higher plants can use them has been proved by Olsen (1923), who showed that provided the production of excessive acidity is avoided, ammonium salts and nitrates can both be used.

Again, owing to the variations in the distribution of the plankton it is impossible to form a direct estimate of the seasonal crop. Calculations based upon the changes in the minor chemical constituents of the water afford, however, an estimate which is trustworthy provided the conditions which limit their applicability be borne in mind.

Furthermore a mass of evidence has been produced in support of Nathansohn's (1906) views regarding the importance of the vertical circulation of the water in connection with the production of an abundant plankton.

Of the minor constituents studied so far it has been established that phosphate and under certain conditions nitrate may limit the production of the phytoplankton.

In conclusion the writer desires to express his thanks to Prof. H. H. Dixon and to Dr. H. H. Poole for their help in revising this paper, also to Dr. E. J. Allen and Mr. H. W. Harvey for assistance with the literature of the subject and to the Marine Biological Association of the United Kingdom and the Royal Dublin Society for the loan of the blocks for the figures.

Summary.

The action of the phytoplankton in removing carbon dioxide from sea water results in an increase in alkalinity in the surface 20 metres; this becomes extended to the bottom of the English Channel in October owing to vertical mixing. The amount of photosynthesis is equivalent to one kilogram of glucose in a water column 83.3 m. deep with surface area four square metres.

The phosphate content of sea water decreases in spring and increases in autumn. In the English Channel at Station E 1, depth 70 m., the annual consumption is close to 30 mg. P_2O_5 per m^3, corresponding to the production of 1.4 kg. of phytoplankton, wet weight, for the one square metre water column, or 1,400 metric tons per sq. kilometre. Assuming a 15 per cent. carbohydrate content the alkalinity measure-

ments also indicate 1,400 tons; the exact agreement is fortuitous but the methods afford mutual support. In spring all the surface phosphate is used up and as the year advances but little is left at the bottom in the English Channel. Lack of phosphate apparently limits the production of phytoplankton in spring, and later in summer lack of nitrate may also set a limit. Both are regenerated ceaselessly and accumulate when light is insufficient for rapid growth. The dark ocean depths sewe as store-houses for these nutritive salts.

There is no proof that silica is ever a factor limiting diatom production in the ocean, though in spring the small amount present becomes much reduced.

In certain fresh waters the variations in the salts necessary for plant growth are much greater than in the sea.

The data presented furnish reasons for the proved richness of northern and coastal waters and support NATHANSON's views.

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Age Determination of Eels from Norfolk and Cumberland

by

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Copenhagen.

The present investigation on the growth of eels is based on samples from these two localities:

1. 198 specimens from Norfolk: St. Benedict's Abbey; 1 mile W. of junction of Rivers Bure and Thurn. 13th December 1920.
2. 119 specimens from Cumberland: Newby Bridge, Windermere. 18th—20th December 1920.

The material in question has been furnished by the Fisheries Laboratory in Lowestoft and sent preserved in formaline to Prof. Johs. Schmidt, Carlsberg Laboratorium, Copenhagen, who has entrusted the work of age determinations to my care.

The age determination is especially based on countings of the scale rings, but a smaller number of otoliths (from 50 specimens of each sample) have also been used. As far the greater part of the otoliths belong to older fish, it has very often been impossible to read the number of growth rings with absolute accuracy. The age determinations are therefore mainly based on countings of the growth rings in the scales and the age determinations have therefore only a relative value.

The sex of the fish, its total length and weight have been noted.

The sample from Norfolk contains 51 females and 147 males and the sample from Cumberland only females (119 spec.).

Norfolk. The total length of the males varies from 29 to 45 cm. and the length of the females from 36—73 cm. The following table shows the number of specimens and the average length of the various year-groups (number of growth rings in the scales). In addition to the average length, the range of variation for all specimens of the respective year-groups has also been noted.

Table I.

Number of scale rings	♂			♀		
	Number of spec.	Average length cm.	Range of variation cm.	Number of spec.	Average length cm.	Range of variation cm.
III	2	31.5	31—32	..	..	..
IV	3	30.0	29—32	2	38.0	38
V	25	34.4	29—40	2	38.5	36—41
VI	81	34.7	30—39	2	49.0	49
VII	33	35.8	32—41	14	49.3	45—58
VIII	3	39.3	36—45	19	52.2	41—73
IX	..	..	..	6	57.0	49—65
X	..	..	..	5	61.0	52—73
XI	..	..	..	1	65.0	65

The main part of the males have 5—7 rings and the greater part of the females have 7—8 growth rings in the scales. The oldest males have 8 growth rings while the oldest female has 11 rings in the scales.

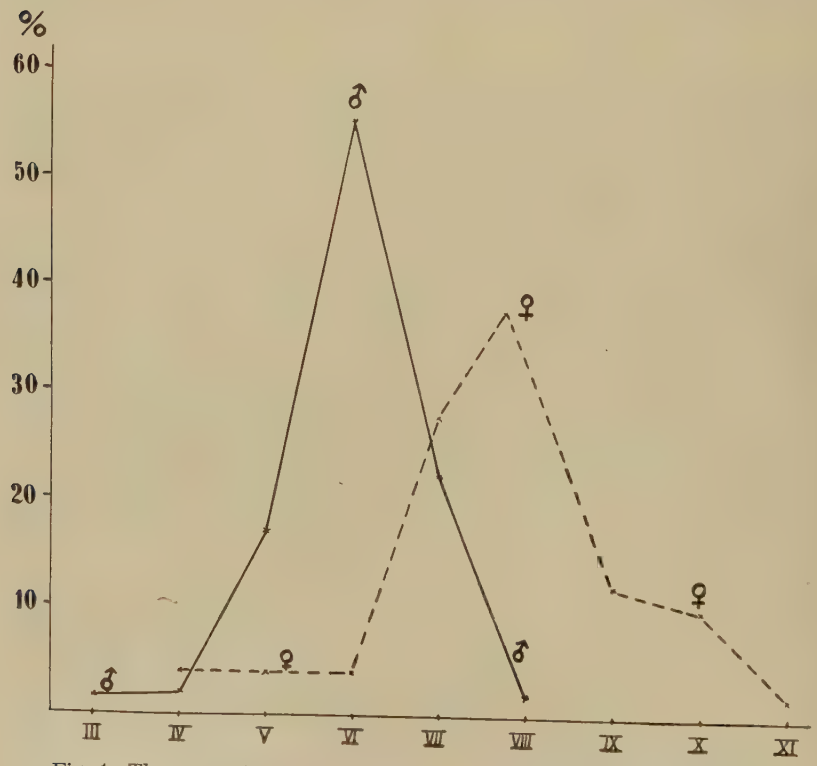

Fig. 1. The percentage of the different year-groups. Norfolk, Dec. 1920.

The percentage of the different year-groups of the two sexes will be seen in the graph fig. 1. It is a wellknown fact, that the males of the eels only reach a size about 40—45 cm. and all the eels of greater size are only

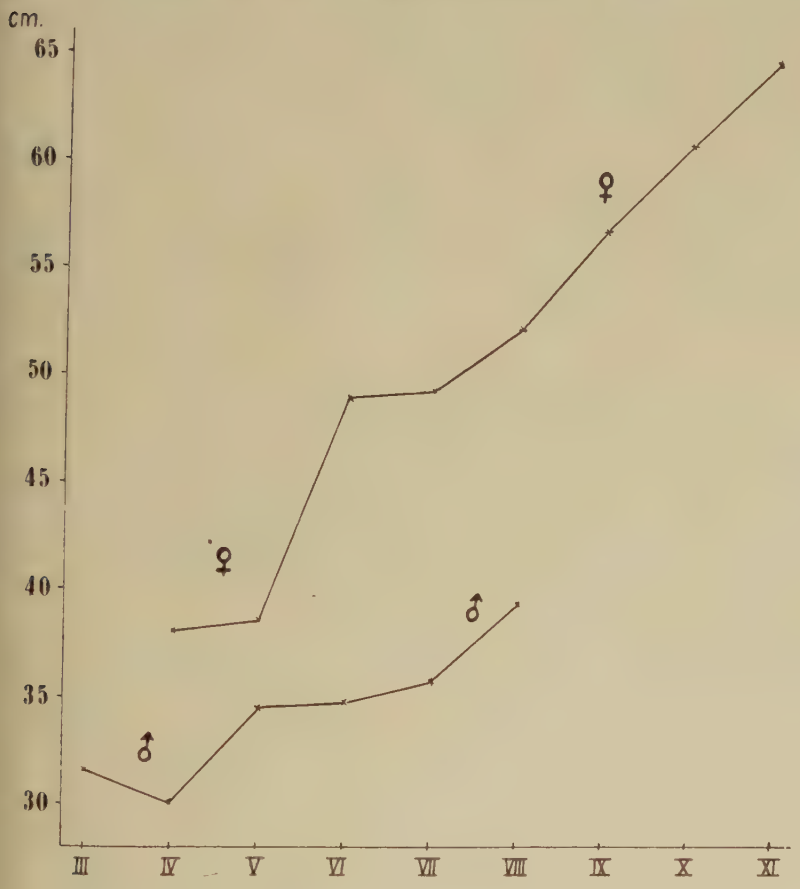

Fig. 2. The growth curves of males and females. Norfolk, Dec. 1920.

females. The difference in the growth curve of the two sexes will be seen very clearly from the graph fig. 2, where III—XI represent the various year-groups.

Considering the weight of the two sexes of eels from Norfolk we find the weight for the different year-groups as shown in table II p. 230.

In accordance with the length of the two sexes, we find that the increase of weight of the males per year is very little in comparison with the increase of the females. The average growth of the males from group V to VIII is e. g. only 38 gr., while the average growth of the

Table II.

Number of scale rings	♂			♀		
	Number of spec.	Average weight gr.	Range of variation gr.	Number of spec.	Average weight gr.	Range of variation gr.
III	2	42	35— 50	..	..	..
IV	3	45	35— 55	2	85	80— 90
V	25	73	30—115	2	97	65—130
VI	81	74	40—115	2	242	240—245
VII	33	80	50—130	14	222	155—385
VIII	3	111	90—150	19	280	150—680
IX	..	..	..	6	375	190—650
X	..	..	..	5	479	265—735
XI	..	..	..	1	545	545

females is 193 gr. for the same group. It must be remembered that the present material only contains eels of the older year-groups.

Cumberland. All the eels from Cumberland are females and the range of variation in total length is from 44 to 88 cm. The following table shows the number of specimens, the average length and the range of variation for the various year-groups:

Table III.

Number of scale rings	Number of specimens	Average length cm.	Range of variation cm.
VIII	17	47.8	44—50
IX	39	50.5	45—58
X	29	53.7	50—60
XI	17	55.6	48—74
XII	7	61.9	54—87
XIII	5	64.0	58—80
XIV	2	85.0	84—86
XV	1	(73.0)	..
XVI	..	..	..
XVII	1	(88.0)	..
XVIII	1	(83.0)	..

It will be seen that the greater part of the eels from Cumberland have 8—11 growth rings in the scales. The growth of the eels presents, as will be seen, a fairly regular course, in spite of the inadequacy of the material in the case of the older groups. The irregularity among the oldest groups is moreover due first and foremost to the wide range of variation in size

The average weight of eels from Cumberland will be seen from the following:

Table IV.

Number of scale rings	Number of specimens	Average weight gr.	Range of variation gr.
VIII	17	185	145— 230
IX	39	230	150— 525
X	29	300	180— 540
XI	17	350	190— 800
XII	7	324	255— 375
XIII	5	479	360— 865
XIV	2	1315	1265—1365
XV	1	(925)	..
XVI	..	..	..
XVII	1	(1250)	..
XVIII	1	(1720)	..

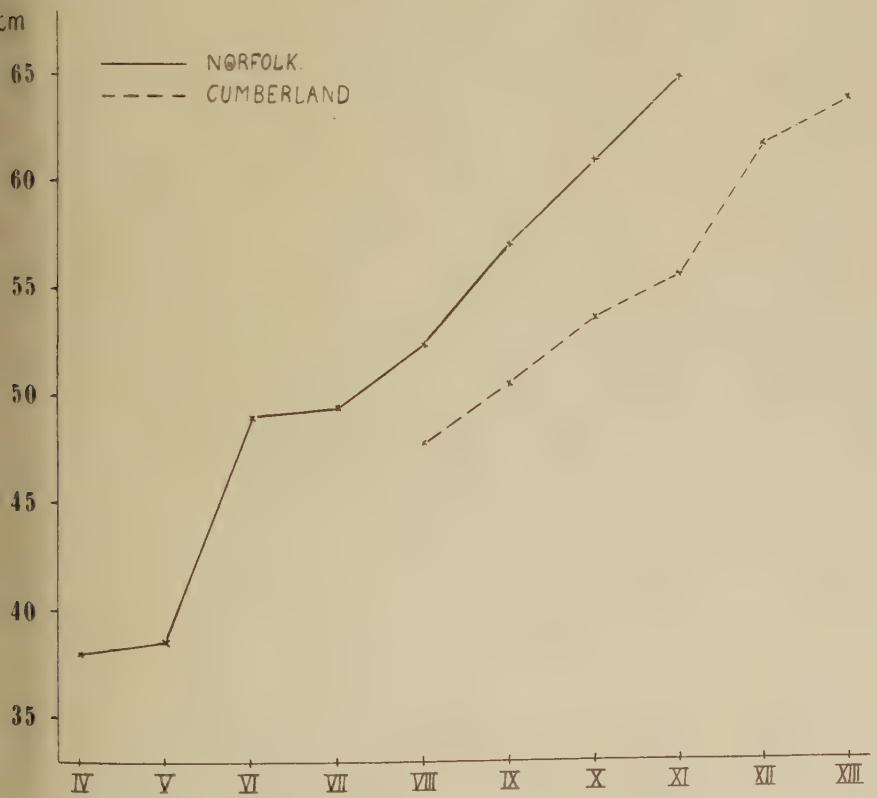

Fig. 3. The growth curves of females from Norfolk and Cumberland. Dec. 1920.

The material for the older groups is very small, but the growth curve from the year-group VIII to XIII shows a nearly regular course.

Now it is of interest to compare the growth of the eels from Norfolk and from Cumberland. For that purpose we can only use the females because we have got only females from both localities, but the material

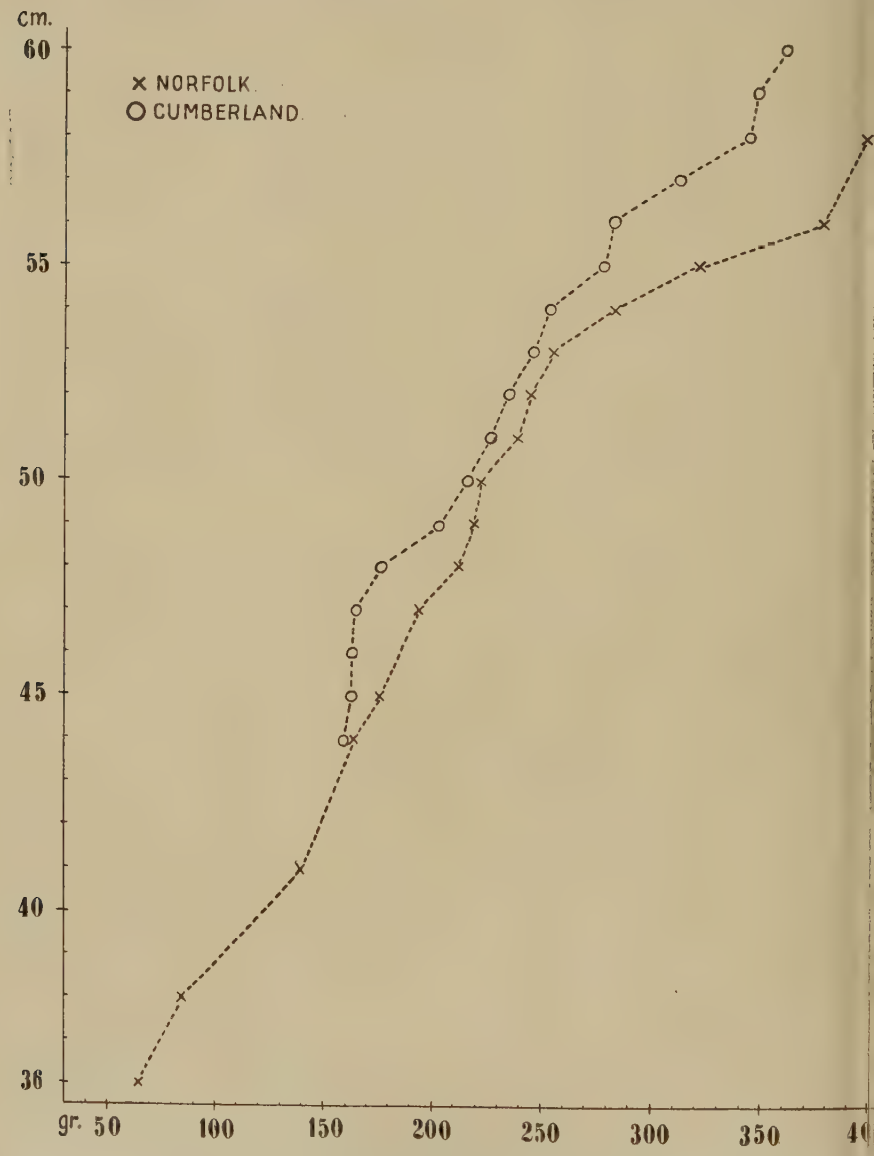

Fig. 4. Ratio between length and weight of females from Norfolk and Cumberland Dec. 1920.

Table V.

Number of scale rings	Average length cm.		Average weight gr.	
	Norfolk	Cumberland	Norfolk	Cumberland
VIII	52.2	47.8	280	185
IX	57.0	50.5	375	230
X	61.0	53.7	479	300
XI	65.0	55.6	545	350

of females from Norfolk compared with the females from Cumberland shows the interesting fact, that *the eels from Norfolk reach a relatively greater size than the eels from Cumberland of the same year-group.*

Table VI.

Total length cm.	Norfolk			Cumberland		
	Average weight gr.	Number of spec.	Range of variation gr.	Average weight gr.	Number of spec.	Range of variation gr.
60	330	1	330	362	2	330—395
59	395	2	390—400	350	3	345—355
58	400	2	385—415	346	7	315—395
57	..	..	..	313	3	265—375
56	380	2	300—460	284	8	260—310
55	322	2	310—335	280	5	255—300
54	285	1	285	255	9	230—310
53	257	2	250—265	248	6	220—290
52	246	4	225—265	237	9	185—290
51	240	1	240	228	10	200—250
50	222	3	200—235	218	11	180—255
49	220	7	190—245	205	8	170—235
48	212	3	200—220	178	9	150—205
47	195	2	190—200	167	6	150—185
46	165	3	155—180	164	5	145—190
45	177	2	175—180	164	4	155—180
44	165	2	160—170	160	1	160
43	..	..	..	..	..	..
42	..	..	..	..	..	..
41	140	2	130—150	..	..	..
40	..	..	..	..	.	..
39	..	..	..	..	..	..
38	85	2	80—90	..	..	..
37	..	..	..	..	..	..
36	65	1	65	..	..	..

It is only possible to compare the four year-groups (VIII—XI growth rings), but the result is very convincing (see fig. 3). The table V p. 233 gives the average length and weight of the four year-groups from the two localities.

It appears from this comparison that there seems to be an essential difference in the growth of the eels from the two localities and the comparison shows that the growth of the eel takes place at a considerably more rapid rate in Norfolk than in Cumberland.

For still further illustrating the difference between the growth of the eels in the two localities we shall consider another circumstance. The ratio between length and weight of the specimens from Norfolk and Cumberland shows the condition of the eels in the two places. The average increment of weight per cm. total length for the various sizes of females ranging from 36 to 60 cm. total length is shown in table VI, p. 233.

A further illustration of the proportionate increase in weight with increasing length is afforded by the accompanying graphical chart (fig. 4) drawn up for specimens from the two localities. It will be noticed that the eels from Norfolk for the various sizes reach a relatively higher weight than the eels from Cumberland. That means, that the condition of the eels from the first mentioned locality is relatively better than in the last named place.

This fact also points in the direction, that the eels find more favourable conditions in Norfolk, and less favourable in Cumberland.

Graphical Calculation of specific volume and dynamic depth

by

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The calculation of the specific density and volume of sea water is a very laborious process, involving much tedious interpolation in the Knudsen tables and the tabulation of a number of correction terms to be added in order to find the value of the specific density (or volume) *in situ*. Besides the great amount of labour in calculation, the usual method involves a serious degree of inaccuracy, as the linear interpolation from the Knudsen tables giving values for each entire degree C. is bound to produce an error, the variation with temperature being by no means linear, and the tables of correction terms for the variation of the compressibility with salinity and with temperature give the values in too great steps.

These disadvantages can be obviated, and a saving of about 75 per cent of labour attained, by using the graphical method to be described.

The main implement is a chart containing curves (really straight lines) representing for each temperature interval of 0°2 C. the relation between salinity and specific volume. It has been found convenient to use squared paper with 2 mm. squares, in sheets of 60 by 45 cm. The best scale will then be one square pr. 0.01 $^{0}/_{00}$ of salinity (abscissae) and one square for the 5th decimal of sp. volume. It is necessary to use such a liberal scale in order not to loose in the calculation any of the accuracy which may be obtained in titration and in determination of temperature. A sheet of the size mentioned will still give room for a sufficient interval of values for a given area and a given season. I have e. g. had charts made for (1) the coast of Norway during winter and spring, and (2) North Sea—Faeroe during summer. The right lower corner of the first named is shown in fig. 2.

The second implement to be made is a chart (fig. 1) from which the correction for variation of compressibility with temperature and with salinity can be read off simply by marking off with a pencil on the

edge of a slip of paper the distance found on the chart by placing the slip thereon in the requisite manner.

The third implement to be used is a set of small paper slips. It has been convenient to enter the observational data on the slips, a work anybody can do. The slips should be printed or stamped beforehand

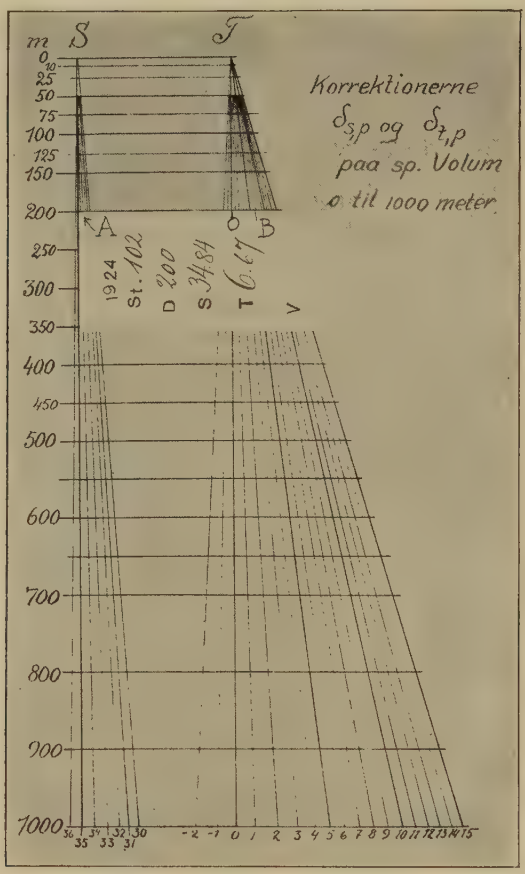


Fig. 1. (About $^1/_2$ nat. size.)

with the necessary headings (year, station, depth, temperature, salinity and sp. vol.). The size of the slip to be about 3 × 7 cm.

The procedure is now as follows:

A slip is placed on the chart (fig. 1) with the edge along the line representing the depth recorded on the slip and with the left hand corner (A) at the perpendicular line marked S—35. The point on the slip which coincides with the line T—0 is marked off on the edge of the slip (O),

and this is moved horizontally till the left hand corner (A) touches the point in the left hand line system representing the salinity recorded on the slip. Then the line of temperature in the right hand system is found and its intersection with the slip marked off on the lastnamed — using a special mark (B in fig. 1 and 2) in order to distinguish it from

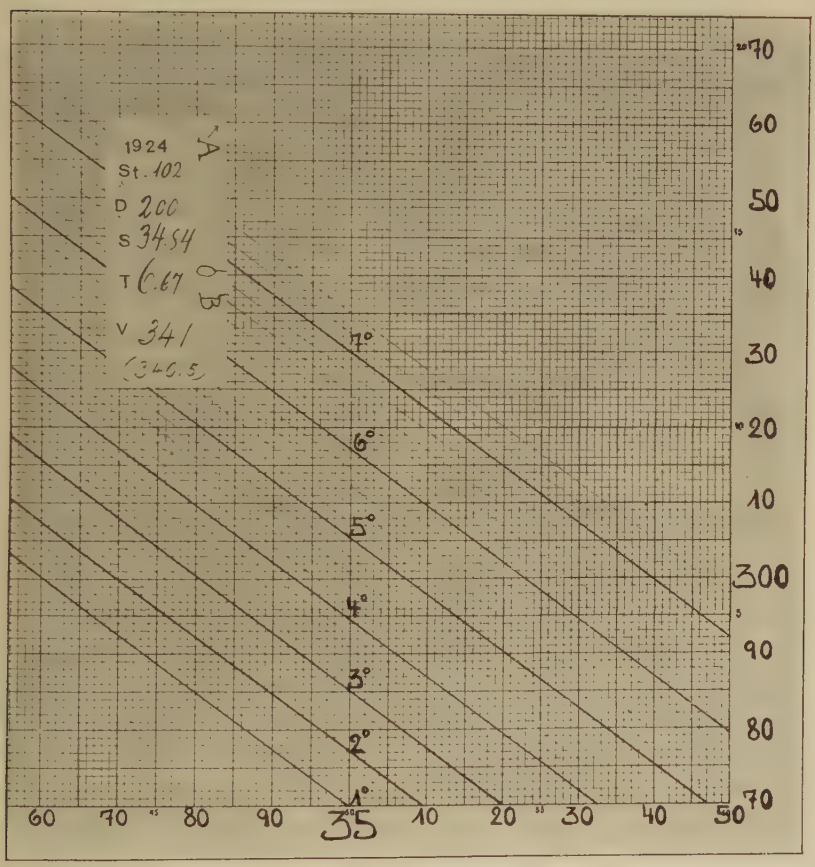


Fig. 2. (About 1/2 nat. size.)

the first mark. It is, of course, convenient to go on at this stage of the process till all the slips are done with. Each slip is then placed vertically on the main chart.

The second mark (B) is placed at the point in the chart corresponding to the temperature and salinity recorded on the slip, and the specific volume is read off on the horizontal intersecting the edge of the slip through the first mark (O). The values so found are then written down

at the foot of the slip, whence they are subsequently transferred to the fourth column of the tables. If the dynamical depths are desired two more columns have to be added — one for the mean sp. volumes for the intervals between the observation depths and the second for the dynamical depths, which are easily obtained by multiplying the sp. volumes by the depth-intervals and continuously adding the products.

As a further simplification of the tabulation work one can dispense with the two first figures of the sp. volume, writing f. inst. 341 for 0,97341. The figures for dynamical depths will then also need completion in order to give the actual dynamical depths in metres which may be seen from the following:

if α be the sp. volume
D be the dynamical depth in metres
v be the suggested simplified expression for the sp. volume
d the corresponding expression for the dynamical depth
p the actual depth (or pressure)

$$v = (\alpha - 0.97) \cdot 10^5$$
$$\alpha = 0.97 + v \cdot 10^{-5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$
$$d = \sum_0^p v \, \Delta p$$
$$D = \sum_0^p \alpha \, \Delta p = \sum_0^p (0.97 + v \cdot 10^{-5}) \, \Delta p$$
$$= \sum_0^p 0.97 \, \Delta p + 10^{-5} \sum_0^p v \, \Delta p$$
$$D = 0.97 \, p + 10^{-5} \cdot d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

It is consequently very easy to find the dynamical depth D from the number calculated by the above method, d: it suffices to subtract 3 per cent from the depth and add d after having moved its decimal point 5 places to the left.

For the calculation of gradients this process is of course quite unnecessary. As the question in this case always is about differences of dynamical depths, it is more convenient to handle the volumes d than the clumsy array of figures necessary to give the accurate expression for D.

In the method described above no provision is made for introducting the compressibility itself as affected by depth (or pressure), only the variations of the compressibility caused by temperatures differing from 0° and salinities differing from 35 per mille. This omission is intentional, as it is quite unnecessary, when differences of dynamical depths for corresponding pressures are sought, to introduce a correction to the sp. volumes which will disappear as soon as these are used for

the desired end. If wanted, this correction is better introduced numerically into the table as the values are so great in comparison with those of the two corrections considered, that the charts and slips would be too unwieldy.

The following example shows the simplicity of the calculation table according to this method:

»Johan Hjort«, Vestfjorden, 1924 st. 102.

Depth	T	S	v	$d \cdot 10^{-2}$
m.	C.°	‰	$(\alpha - 0.97)\ 10^{-5}$	mm.
0	1.91	33.29	406	0
10	2.06	31	405	41
25	06	28	407	101
50	10	29	407	203
75	3.14	47	402	304
88	4.91	91	386	356
100	5.39	34.13	376	401
150	6.64	65	354	584
200	67	84	341	757
365	56	93	335	1314
370	50	96	332	1331

In this table the values for d are given minus the two last places, the remaining figures ($d \cdot 10^{-2}$) thus representing millimeters, the smallest unit of any importance in this connection.

As to accuracy, it may safely be contended that this graphical method gives better results than the numerical calculation, where all terms are handled in the same unit as that used to express the result. By calculating graphically from accurate diagrams, any summation of errors arising from steps in the different tables is avoided. It is also probable that the chance of great errors is less than in numerical calculation, though this is of less importance as the work has to be revised carefully in any case.

It will be noted that the example given of a calculation table contains only 5 columns as against at least 12 necessary for the corresponding numerical work, no column being set aside in any case for the mean values of v (to be multiplied by Δp and continuously summed up to form the values d — respectively α and D). If a calculating machine of the type Brunsviga or Triumphator is used it is extremely easy to arrive at the values d without having to perform the tedious formation of

means for each interval. In the above example the calculation is done thus: the left hand pointer on the machine is set to one in order to give the depths in the result. To the right the first value for v, ($v = 406$) is set and turned 5 times, then the value v_{10} which is turned 5 times till 10 is shown to the left. The result is 4055, or, with exclusion of 2 places, 41, to be introduced into the table. The value $v_{10} = 405$ is now turned till the depth intermediate between 10 and 25 is shown to the left (17), then the value $v_{25} = 407$ is set in place of $v_{10} = 405$ and so on. The small inaccuracy involved in taking 17 as the mid-way point between 10 and 25 is quite infinitesimal against the greater and scarcely avoidable error in assuming the sp. volume to vary as a linear function within the intervals between the observational depths. By using mean values of v none of the values d in the example would be altered by a single unit. But if a graph is constructed to represent the variation of v with depth the smoothed curve and the linear connections between the points will include areas of a size corresponding to one unit (mm.) in d from 200 downwards. The most probable values to be arrived at for d_{200}, d_{365} and d_{370} are consequently 756, 1313 and 1330 instead of 757, 1314 and 1331 respectively. As the error generally will not amount to much more than this, it is not worth while to consider it.

The construction of the charts.

The main chart is constructed from a series of calculated values of v for each entire $^0/_{00}$ of salinity required. As the variation of sp. volume is nearly linear it is quite sufficient to calculate values for each degree, for each entire $^0/_{00}$ S. (If one only had values for every second $^0/_{00}$ S. the maximum error would be one unit in v. As values are actually provided for *each* $^0/_{00}$ S., the maximum error is consequently only about one fourth of this, or quite negligible). As an integer value of S. corresponds to a fractional σ_0, it is necessary to make this interpolation graphically. The calculation should be done with one figure more in v — i. e. four places.

The series of values for v have now to be slightly smoothed by examining their first and second differences, in order to make the subtabulation of intermediate values for each 0°2 C. possible. The process of subtabulation is described in many textbooks on calculation work and need not be gone into here.

The auxiliary chart shown in fig. 1 is constructed from the figures given by Hesselberg & Sverdrup (Beitrag zur Berechnung der Druck- und Massenverteilung im Meere. Bergens Museums Aarbok 1914—15,

nr. 14). It is constructed on paper of the same kind as the main chart, but it may with advantage be drawn on white paper and multiplied by photographic contact printing. Prints of such a chart for depths 0—1000 m. with temperatures up to 15° C. and another for depths 1000—3000 m. and temperatures up to 4° C., will be supplied upon request. Fig. 1 is made from such a print.

Correction of temperatures

by

Oscar Sund.
Bureau of Fisheries, Bergen.

The use of reversing thermometers involves a great deal of tedious calculation to find the true temperature in situ (Tk) from the observed temperatures of the main thermometer ($T°$) and of the correction thermometer ($t°$). In order to facilitate this calculation and make it possible to have it done at once on board, a graphical representation of the figures given in the certificate belonging to each instrument should be made. The type of charts used on board the "Johan Hjort" are drawn according to a calculation of the corrections for the standard temperatures given in the certificate. The correction is commonly calculated from the formula

$$k = (T - t)\ (T + v)\ q + I = dsq + I \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where I = index error of main thermometer

v = volume of mercury down to 0°

q = coefficient of thermal expansion of mercury = $\frac{1}{6300}$ (strictly speaking the combined effect of the thermal expansion of the mercury and the thermometer tube containing it).

t = temperature shown on auxiliary thermometer, corrected for index error

$d = T - t$

$s = T + v$

This formula is evidently slightly incomplete, since the T used there is the observed value, while it should be the corrected value of T, which is impossible to do in a formula to be calculated from. But the same end is attained if to the above formula is added another term making up for the small error mentioned (which never amounts to more than 0°02 C.). One could write

$$\text{total correction} = K = dsq + I + (dsq + I)\ sq \quad \ldots\ldots\ldots\ldots (2)$$

To use this formula when calculating individual temperatures is clearly out of the question, but it may easily be taken into account if

the calculation is once for all and represented graphically and the individual temperatures corrected from a chart. In this way more accurate results and a very considerable saving of time and trouble are achieved.

Example: The following data are given in the certificate:

Therm nr. 764.

$v = 111°$

$I\,(0°) = 0.03$, $I\,(4°) = 0.01$, $I\,(8°) = 0.04$, $I\,(12°) = 0.03$, $I\,(16°) = 0.02$

Index error of auxiliary thermom. $= i\,(0°) = 0.1$, $i\,(10°) = 0.2$, $i\,(20°) = 0.1$, $i\,(30°) = 0.2$

These are inserted into the following form which has been found convenient for rapid calculation.

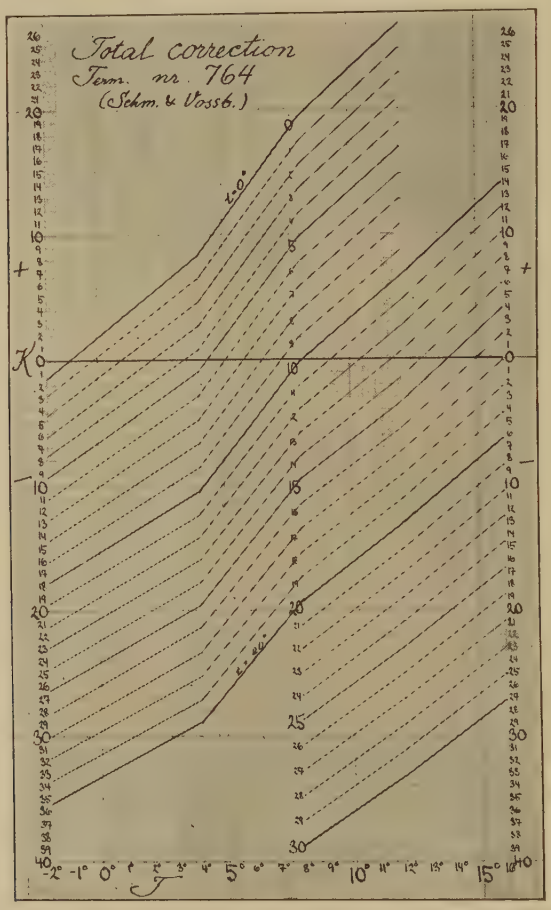
Calculation of thermometer Corrections.

(Corrections K, given in thousandths of degree C).

Nr.			764						1062	
T = ...	$t+i$		0°	4°	8°	12°	16°	$t+i$	0	4°
s = ...			*111*	*115*	*119*	*123*	*127*		..	..
sq = ...			1764	1828	1891	1955	2020		..	..
I = ...			*30*	*10*	*40*	*30*	*20*		..	..
d			*—0.1*	*3.9*	*7.9*	*11.9*	*15.9*		..	..
dsq			—2	71	149	233	321		..	..
$dsq + I$		*0.1*	28	81	189	263	341		..	..
$(dsq + I)\,sq$ ..			0	2	4	5	7		..	..
K			**28**	**83**	**193**	**268**	**348**		..	..
d			*—10.2*	*—6.2*	*—2.2*	*1.8*	*5.8*		..	..
dsq			—180	—113	—42	35	117		..	..
$dsq + I$		*10.2*	—150	—103	—2	65	137		..	..
$(dsq + I)\,sq$ ..			—3	—2	0	1	3		..	..
K			**—153**	**—105**	**—2**	**66**	**140**		..	..
d			*—20.1*	*—16.1*	*—12.1*	*—8.1*	*—4.1*		..	..
dsq			—356	—294	—229	—158	—83		..	..
$dsq + I$		*20.1*	—326	—284	—189	—128	—63		..	..
$(dsq + I)\,sq$ ..			—6	—5	—4	—3	—1		..	..
K			**—332**	**—289**	**—193**	**—131**	**—64**		..	..
d			*—30.2*	*—26.2*	*—22.2*	*—18.2*	*—14.2*		..	..
dsq			—536	—479	—420	—356	—287		..	..
$dsq + I$		*30.2*	—506	—469	—380	—326	—267		..	..
$(dsq + I)\,sq$ ..			—9	—9	—7	—6	—5		..	..
K			**—515**	**—478**	**—387**	**—332**	**—272**		..	..

The chart is drawn on millimetre paper with T as abscissae and K as ordinates, the different values of t being represented each by a separate

broken curve. The table furnishes four such curves for t (for 0,10, 20 and 30 degr.). The curves for 5°, 15° and 25° can be interpolated by putting in intermediate points between those calculated from the table, in such a manner that these new points are placed at distances from the nearest calculated points above and below proportionally to the consecutive distances between these. The necessary points to draw the curves for all auxiliary temperatures divisible by 5 being now supplied, the points for 2°, 3°, 4°, 6°, 7°, etc. are found by simple linear inter-



(About 1/3 nat. size).

polation and the corresponding points are connected. The figure will give some idea of the charts. The work of constructing charts for a dozen thermometers is done in a few hours and this initial labour is amply repaid, the correction of a temperature reading being now a matter of, say, 20 seconds instead of 4 or 5 minutes as required for direct calculation.

Oil Pollution.

The effect of oil pollution upon certain forms of aquatic life and experiments upon the rate of absorption, through films of various fuel oils, of atmospheric oxygen by seawater

by

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From about the year 1906 an increasing number of vessels have been using oil as a fuel. The oil has been used for raising steam and for use in internal combustion engines of the Diesel and semi-Diesel type.

Ease and rapidity in bunkering, increased cargo space, smaller engine staffs and greatly increased economy in running have led to the very general adoption of fuel oil and it is almost universally used for steam-raising in the Navies of the world and in passenger liners. The tendency today is towards the supplanting of steam-vessels by Diesel-engined vessels as is shown in the tables below. The interest of this change from the pollution standpoint is that the oils used for Diesels and semi-Diesels appear to be less obnoxious than the thicker oils used for steam-raising.

Motor Ships.

	Deadweight Tonnage	I. H. P.
1923	355,925	127,855
1924	649,265	268,550
1925	1,044,915	420,820

Motor Ship Position in Leading Countries.

Country	Steamers	Motors	% Motors to total
U. K.	646,410	356,480	35.5 %
Germany	88,951	21,675	19.5 %
Italy	75,894	193,572	71.8 %
Holland	34,080	93,045	73.2 %
France	98,310	51,710	34.5 %
Japan	25,670	27,600	51.8 %

World Trend of Construction.

	30/6/24	30/6/25	Increase or Decrease
Steamers.....	1,785,480 tons	1,212,525 tons	32 % decrease
Motor Ships....	810,655 —	1,129,912 —	39.3 % increase
Totals	2,596,135 —	2,342,437 —	9.8 % decrease

Trend of Construction in U. K. only.

	30/6/24	30/6/25	Increase or Decrease
Steamers.....	1,157,406 tons	687,607 tons	40.6 % decrease
Motor Ships....	355,590 —	399,070 —	12.2 % increase
Totals	1,512,996 —	1,086,677 —	28.2 % decrease

At the time of writing England is making nearly 44 % of the world's motor tonnage.

Of the steamers being launched a great proportion are oil-burners. Many authorities believe that the coal-burning vessel will be obsolete in the next generation but there are some authorities, notably Sir John Biles, who believe that improved steam engines and better methods of utilising coal will enable the coal-burning steamer of the future to hold its own easily with the vessel using oil fuel.

Ships which carry oil in bulk are:—

1) Oil tankers which use the oil-tanks also for water ballast.

2) Ships which carry oil-fuel in double bottoms which double bottoms are frequently used for ballast tanks.

3) Ships which carry oil-fuel in bunkers only.

4) Ships which carry fuel in both bunkers and double bottoms, which latter are also used for ballasting purposes.

At one time it was considered better to carry fuel in bunkers rather than in the double bottoms because it reduced the possibility of water getting into the oil. Cases have been known where Diesel-engined ships have been disabled through water getting into the oil and stopping the engines. The tendency nowadays, however, is to store the oil in the double bottoms and to extract any water before use by means of centrifuges or special filters. In Diesel Oil it is quite usual to find 80 pounds of water and $^3/_4$ pound of sand in 10 tons of oil. The use of fuel purifiers may now be regarded as almost universal on Diesel-engined ships — one well-known firm alone have, during the last few years, fitted centrifugal purifiers on over 1500 vessels.

As fuel-oil is consumed water is run in to take its place. Before taking on fresh supplies of fuel this ballast-water, which contains 5 % and over of oil, must be pumped into the sea. In view of the number of vessels

using oil-fuel it is obvious that a considerable quantity of oil must gain access to the sea.

An American oil expert has stated that 1,500,000 gallons of oil are discharged daily into the sea.

It might be thought that the oil-purifiers now generally carried on Diesel-engined vessels could also be used for removing oil from ballast-water. Unfortunately it has not yet been found possible to design a separator which will perform the two operations efficiently. In practice it has been found that for removing small quantities of water from oil the centrifuge is more efficient but that for removing small quantities of oil from water filtration through a material resembling felt gives the better results.

Of recent years pollution by oil has assumed grave proportions. Oil has fouled beaches and thus destroyed the amenities of many seaside resorts, floating oil-films have been the cause of fires in harbours and innumerable birds have perished miserably through the clogging of their wings and beaks.

It is also asserted that oil pollution has a deleterious effect upon fish and other marine organisms. In this paper an attempt is made to summarise some of the work that has been already done on this subject and, in addition, the results of a number of experiments are given.

Oil pollution might affect marine life in any of the following ways:--

1) An oil-film might interfere with the exchange of gases between air and water. For instance an oil-film might prevent the absorption by the sea of atmospheric oxygen.

2) The oil-films might affect the marine plants by cutting off the light-rays essential for photo-synthesis.

3) The oils might contain soluble toxins.

4) The oils might form emulsions which would have an adverse effect upon marine life.

5) The oil-films might affect fish-eggs and other floating organisms.

6) The heavier portions of the oils, such as the asphalts, might sink to the bottom after the evaporation of the more volatile oils. These asphalts might then cover and destroy shell-fish beds etc.

Each of the above points will now be dealt with:—

Gaseous exchange through an oil-film.

Before giving the results of actual experiments upon the gas exchange through an oil-film it would be as well to discuss:—

a) Certain aspects of gas exchange between air and natural waters.

b) The spreading of oil-films.

It is quite commonly believed that the dissolved oxygen found in seawater is mostly derived from the atmosphere. Although it is true that dissolved oxygen is derived from the air, by far the greater part comes from marine plants which evolve large quantities of oxygen.

It has been shown by Prideaux, Moore and Herdman that green algae can remove CO_2 from the bicarbonates in seawater until the completion of the following transformation:—

$$R(HCO_3) \rightleftarrows RCO_3 + H_2O + CO_2$$

The evolution of oxygen by plants is caused by their synthesising starch from carbon dioxide.

The great activity of marine plants in evolving oxygen is shown by the fact that the surface layers of the sea are normally supersaturated with oxygen. The existence of this supersaturation has been demonstrated by Gehrke, Schultz, Butler, Coste and others.

There are three possible explanations for this supersaturation:—

1) A body of oxygen-saturated cold water (such as a Polar current) would become much supersaturated if its temperature were raised.

2) A fall in barometric pressure might result in supersaturation.

3) The supersaturation might be due to plant activity.

If the supersaturation were due to causes 1) and 2) one would expect to find the water supersaturated with nitrogen as well as oxygen but Butler and East have found that in seawater supersaturated with oxygen, nitrogen was only present in approximately the amounts necessary for saturation. The results of their analyses are given in this table:—

Place	Date	Temp.	Chlorine	Dissolved gases in cc.s per litre Oxygen	Nitrogen	Percentage saturation Oxygen	Nitrogen
West Oaze .	June 12	17.7°	1860	8.1	11.1	134	104
Nore	— 14	18.0°	1845	7.9	11.0	150	104
—	— 15	18.6°	1860	8.5	10.7	162	102
—	— 18	19.7°	1870	7.44	10.7	145	104
Chapman ..	— 19	20.3°	1505	4.89	11.0	90	104
West Oaze .	— 22	19.1°	1875	6.13	10.5	119	101

Additional evidence that supersaturation is due to plant activity is that the times of maximum supersaturation are in May and June (Butler and Coste) when photosynthesis is at its height on account of the increased amount of daylight and the increased velocity of the reaction caused by the increased temperature.

There is little doubt that the sea acts as a great stabiliser of the atmo-

sphere — it absorbs quantities of carbon dioxide and gives off, when agitated, much oxygen. As an example of the oxygen-emitting power of seawater it may be pointed out that 12 square miles of sea, 15 feet deep and 10 % supersaturation would, if lashed into waves by a wind, give off over 10 tons of oxygen.

It would seem therefore, that even if a film did interfere with gaseous exchange between water and air there would be more than sufficient oxygen in the seawater to support animal life.

Of course, plants will only give off oxygen in the presence of sunlight (or strong diffused light) and it might be contended that an oil-film would cut off vital light-rays. The oil-film, however, would be so thin, about one ten millionth of an inch, that it would be substantially transparent to all light-rays.

There is a likelihood, however, that even a thin film would cut off the light-rays essential for photo-synthesis. The more active of these rays would appear to be in the red and violet portions of the spectrum. The following results obtained by WURMSER are of interest:—

Plant — Ulva lactuca.

Absorption of light of different wave-lengths and photo-synthesis.

Wave-length in $\mu\mu$	Assimilation (x)	Energy absorbed (E)	$\frac{x}{E}$
750—560 (red)	100	100	1.0
560—460 (green)	24	6	4.0
460 downwards (violet)	80	34	2.35

According to LEGENDRE the rate of photo-synthesis of the seaweeds *Ulva lactuca* and *Fucus serratus* increases as the density of seawater decreases — the maximum rate is when the density of seawater is 1.01. It would appear, therefore, that more oxygen should be evolved in inshore positions, such as tidal estuaries, where much fresh water enters the sea.

These results are very interesting because it is in such places that there is a great need for an abundance of oxygen as most estuaries are polluted with de-oxygenating organic matter and also are more subject, than the open coast, to concentrations of floating fuel-oil.

Freshwater plants such as *Potamogeton densus* (Close-leaved Pondweed), *Ranunculus aquatilis* (Water Crowfoot) and *Callitriche verna* (Starwort) have been successfully grown under thin films (0.004 cms in thickness) of Gas Oil, Diesel Oil, 600 Seconds Oil and 1500 Seconds Oil.

The experiments were carried out in small cement aquaria so arranged that light could only reach the plants through the oil-films. (See Fig. 1.)

Two groups of experiments were carried out. In one group a constant supply of freshwater ran through the aquaria, the inlet and outlet arrangements of which are shown in the sketch below, from which it will be seen that these operations had no disturbing effect upon the oil-films. The plants grew as luxuriantly in these aquaria as did the plants in the controls.

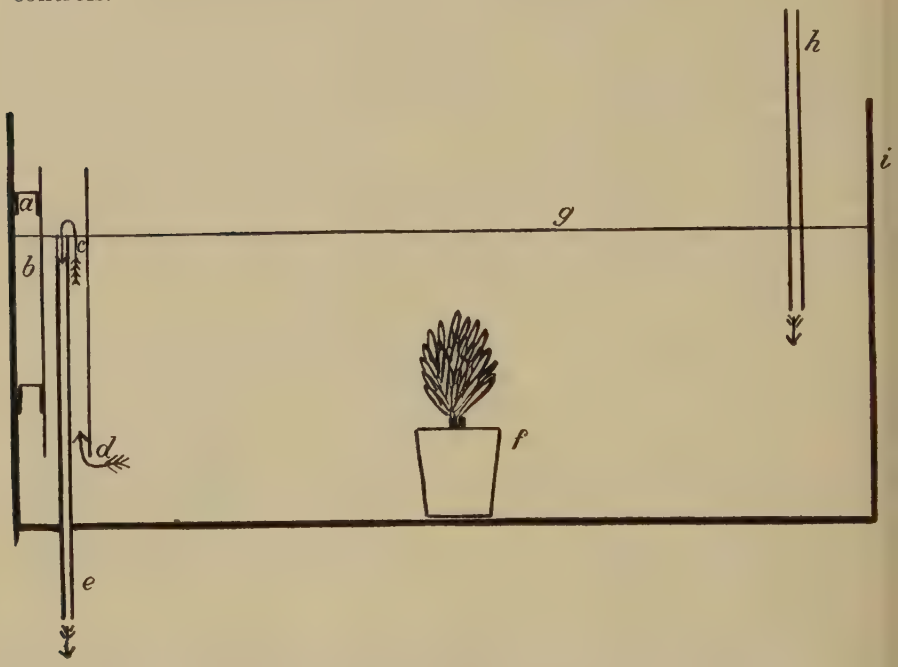

Fig. 1. Apparatus for maintaining a constant supply of water beneath an oil-film, without disturbing this film.

a, Bracket for holding outer outlet pipe. *b*, Semi-siphonic outlet which allows the escape of water but which does not allow the surface oil-film to be sucked down the outlet pipe. *c-d*, Path of escaping water. *e*, Outlet pipe. *f*, Flower pot containing plant under test. *g*, Water level. *h*, Freshwater inlet. *i*, Cement aquarium.

In the other group the water was only changed once a week. Here it was observed that the plants, although they were not killed, hardly grew at all.

These experiments were continued for four months and show that, although oil-pollution might have an adverse effect under stagnant conditions, it would have little effect under conditions likely to be met with at sea.

Spreading of oil-films.

The spreading of oil-films on water has been much studied, particularly by Lord Rayleigh, Devaux, Hoog, Hardy and Langmuir.

The manner in which an oil spreads depends upon the composition of the oil. The carboxyl group has a great affinity for water as is shown by the solubility of organic acids in water as compared with the insolubility of the corresponding hydrocarbons. This affinity is probably due to the residual valency of the oxygen atom. On the other hand hydrocarbons have a greater affinity for one another than for water as is shown by their insolubility in water although they are mutually miscible.

The spreading of an oil upon water is due to an active group in the molecule. Hence when certain oils (e. g. Oleic Acid) are placed on water the carboxyl groups dissolve in the water but the hydrocarbon chains have too much attraction for one another and too little for water to be drawn into solution, but by spreading out so as to form a film one molecule thick, all the carboxyl groups can combine with the water without causing the hydrocarbon chains to become separated from one another.

It follows from the above that a pure hydrocarbon oil, whether an open chain or ring compound, would not spread at all. Hardy found that such oils as benzene and cymene do not spread.

When an unsaturated oil is put upon a water surface the hydrocarbon chains assume a vertical position like corn growing in a field whilst any carboxyl groups present immerse themselves in the water.

An oil-film has a thickness of about 1×10^{-7} centimetres — a triolein film, for instance, has been found by Devaux to have a thickness of 1.13×10^{-7}.

The above remarks apply to the spreading of oils under stringent experimental conditions but in practice and with the usual mixed oils the problem is very much more complex and there is considerable diversity of opinion amongst workers as to the spreading power of various oils. Work of considerable value has been done by Hacker who has studied many of the factors controlling the spread of oil on water.

One of the factors which influence spread is the formation of an invisible film such, for instance, as is given by camphor. The presence of an invisible film caused by grease from the fingers can be demonstrated by sprinkling talc powder on the surface of clean water and then touching this surface with the finger when it will be found that the talc particles will be driven away concentrically by the spreading of an invisible film of grease from the finger. Also, when small crystals of thymol or phenol are thrown upon a clean water surface they will move about briskly but this movement can be checked by greasing the surface of the water by touching it with a finger.

The presence of an invisible film is shown by the fact that thymol crystals will not move upon it and also crude oil and kerosene will not spread upon it.

That it is an invisible film upon the surface which causes these effects and not the presence of some material in solution can be shown by abstracting a sub-surface sample of water, the surface of which has been contaminated. It will be found that, whereas the movement of thymol crystals is inhibited on the surface of the contaminated sample, on the surface of the sub-surface sample this movement is quite brisk.

Crude oil and kerosene do not form invisible films as is shown by the fact that these substances do not prevent the movement of thymol.

It has already been pointed out that a pure hydrocarbon oil will not form a film upon water. Volatile hydrocarbons, however, can form films by evaporation and condensation of their vapours upon the surface of the water. If, however, evaporation is prevented the films contract into blobs.

When the chemically inert hydrocarbons acquire certain radicles they have an attraction for water. According to LANGMUIR the following radicles give a water-affinity to hydrocarbon molecules, -OH, -O-, -COO- and $-NH_2$.

Substances containing the -OH and the -COOH groups when they have a low molecular weight are soluble in water (e. g. Acetic Acid and Ethyl Alcohol) but when they are liquid and insoluble in water they form invisible films (e. g. Octyl Alcohol and Oleic Acid). When solid and slightly soluble they show the movements characteristic of thymol. These substances contain an -OH or a -COOH group which form invisible films and satisfy the attraction of water for active groups; thus they prevent the spread of oils.

Different types of spread are summarised by HACKER thus:—

"1) An invisible film. This is produced by a pure substance containing one active group in the molecule. It is one molecule thick. The active group is adsorbed to the surface of water and exposes a uniform layer of inactive groups which prevents the spread of any other oil.

2) A film due to condensation of the vapour of a volatile hydrocarbon. This may be more than one molecule thick. It collects into a blob like that of pure paraffin if evaporation is prevented. It does not stop other oils spreading on the water.

3) A film containing substances like salicylic acid. This does not prevent the spread of oils. Salicylic acid contains two active groups and the action may be due to one group being adsorbed by the water and the other exposed to attract a further layer of oil.

4) A mixed film. This kind of film shows interference colours; an excess of the oil or of another oil with active groups will spread slowly across it but pure paraffin will not spread.
5) A thick mixed film. This occurs when excess of oil is added to a film which shows colours. The colours disappear and a uniform film of sensible thickness is formed which may be difficult to see. But it differs from an invisible film in that even pure paraffin will spread by diffusing through the surplus oil on the surface."

It will be found that if water is saturated with some substance such as phenol, oil will not spread upon it. It follows that if an oil with spreading properties contains such a substance as phenol it will form blobs when first put upon water. In time, however, the phenol concentrated in the surface layers will diffuse away and then the oil will spread.

A further point now arises, the effect on oils of exposure to air. It is known that crude oils absorb oxygen which fact can be demonstrated by placing oil and indigo in a stoppered flask when it will be found that the indigo will lose colour due to the absorption by the oil of oxygen from the indigo. Hacker found that oxidised samples of oils had an increased spreading power. An oil which showed a marked increase in spreading power was Tarakan Liquid Fuel (Asiatic Petroleum Co.), a crude, undistilled oil, containing aromatic hydrocarbons and kerosene. To a lesser degree he found the Mini and Balik Papan Oils increased in spreading power after exposure to air. These two oils are the residues of crude oil after the removal, by distillation, of benzene and kerosene. Balik Papan contains 50 % of aromatic hydrocarbons, and Mini contains naphthenic hydrocarbons.

Even kerosene exhibits an increase in spreading power due to oxidation. As might be expected, pure paraffin does not increase in spreading power if exposed to the air.

Most tars (natural or distilled) increase the spreading power of oils and Sollman has found that asphalt increases the spreading power of coal oils.

The researches of Hacker show a method of mitigating the nuisance of oil-pollution in constricted waters such as bays and harbours. The spread of an obnoxious oil could be checked by making an invisible film of some inoffensive substance upon the water. It has been shown that a Tamil labourer, who was in the habit of smearing himself with coconut oil could, if he walked through the water, effectively check the spread of crude oil.

Much of the oil seen in harbours leaks from the oil pumps used in bunkering ships. The spread of this oil might be checked by making an

invisible film of oil with, say, coconut oil, round a ship which was taking in oil. The offending fuel oil would then form into large blobs which could be readily scooped up by means of some special device such as is mentioned in the "Scientific American" p. 161, March 1923.

Fuel Oils.

There are four main types of oil used at sea, these are:—

Gas Oil, Diesel Oil } Used in ships driven by internal combustion engines.

600 Seconds Oil, 1500 Seconds Oil } Burned under boilers for steam-raising.

For these experiments four typical oils were kindly supplied by Shell-Mex Ltd. The properties of these oils are given below:—

Gas Oil.

A brownish black mobile liquid which contains no asphalt and very little carbon residue.

Specific Gravity at 15° C.	0.850
Flashpoint P. M. closed	82° C.
Viscosity, Red. 1 at 100° F.	36 secs.
Calorific value in British Thermal units per pound	19850
Asphalt (insoluble in 60/80° C. sulphonated petroleum spirit)	Nil.
Carbon residue (Conradson test)	0.05 %
Pour Test A. S. T. M.	Below 0° F.
Ash	less than 0.01 %

Distillation.

Initial Boiling Point	223° C.
10 %	254° C.
20 %	263° C.
30 %	270° C.
40 %	278° C.
50 %	289° C.
60 %	297° C.
70 %	307° C.
80 %	324° C.
90 %	350° C.

Ultimate analysis.

Carbon	84.4 %
Hydrogen	13.4 %
Sulphur	0.4 %
Oxygen and Nitrogen	1.0 %

In this analysis and also in all the other analyses the quantity of asphalt found (which depends upon the method used) was determined by using 1 gram of oil and 100 ccs of an aromatic-free petroleum spirit boiling between 60° C. and 80° C.

Diesel Oil.

A black mobile liquid which contains about 0.2 % of both carbon residue and asphalt.

Specific Gravity at 15° C.	0.870
Flashpoint P. M. closed	82° C.
Viscosity, Red. 1 at 100° F.	36 secs.
Calorific value in British Thermal units per pound	19,400
Asphalt (insoluble in 60/80° C. sulphonated petroleum spirit)	0.2 %
Carbon residue (Conradson test)	0.2 %
Pour test A. S. T. M.	Below 0° F.
Ash	0.01 %

Distillation.

Initial boiling point	187° C.
10 %	225° C.
20 %	238° C.
30 %	253° C.
40 %	268° C.
50 %	285° C.
60 %	302° C.
70 %	328° C.

Ultimate analysis.

Carbon	84.2 %
Hydrogen	12.8 %
Sulphur	1.1 %
Oxygen and nitrogen	1 % (approx.)

600 Seconds Fuel Oil.

A very viscid black liquid containing over 7 % of asphalt and about 10 % of carbon residue.

Specific Gravity at 15° C.	0.951
Flashpoint P. M. closed	80° C.
Viscosity, Red. 1 at 100° F.	580 secs.
Calorific value in British Thermal units per pound.	18,800
Asphalt (insoluble in 60/80° C. sulphonated petroleum spirit)	7.5 %
Carbon residue (Conradson test)	9.5 %
Pour test A. S. T. M.	Below 0° F.
Ash	0.04 %

Ultimate analysis.

Carbon	84 %
Hydrogen	12 %
Sulphur	3 %
Oxygen and Nitrogen	1 %(approx.)

1500 Seconds Fuel Oil.

A very viscid black liquid containing even more asphalt and carbon residue than the 600 Seconds Oil, namely 9 % of asphalt and 12 % of carbon residue.

Specific Gravity at 15° C.	0.959
Flashpoint P. M. closed	79.5° C.
Viscosity, Red. 1 at 100° F.	1425 secs.
Calorific value in British Thermal units per pound.	18,600
Asphalt (insoluble in 60/80° C. sulphonated petroleum spirit)	9.0 %
Carbon residue (Conradson test)	12 %
Pour Test A. S. T. M.	— 5° F.
Ash	0.05 %

Ultimate analysis.

Carbon	84 %
Hydrogen	11.4 %
Sulphur	3.5 %
Oxygen and Nitrogen	1.1 %(approx.)

THE ABSORPTION OF OXYGEN THROUGH AN OIL-FILM.

That oxygen can penetrate an oil-film can be demonstrated by the following experiment:—

1) Prepare a water-sample in which there is little or no dissolved oxygen. Methods for preparing such a sample will be described later.
2) Float an oil-film upon the surface of this sample.
3) Add 5 cubic centimetres of a solution of Sodium Nitrite and Potassium Iodide (made by dissolving 2 grams of Nitrite, 20 grams of Iodide and a trace of Sodium Hydrate in 100 ccs of water), 5 cubic centimetres of 1 in 4 Sulphuric Acid and 2 cubic centimetres of Starch solution.

If there is any passage of oxygen through the oil-film this will be shown by the sample darkening in colour on account of the release of Iodine caused by the fact that Nitrous Acid will continue to release Iodine in a solution of Hydrogen Iodide as long as air or oxygen gain access to the solution, thus:—

$$2\,HI + 2\,HNO_2 = 1_2 + 2\,NO + 2\,H_2O$$

The liberated NO would act as a carrier and more HI would be decomposed, thus:—

$$2\,HI + O = H_2O + I_2.$$

The method used to determine the rate at which air could penetrate an oil-film will now be described.

An aspirator bottle of 5 litres capacity was filled with River Itchen water of approximately the following composition:—

	Parts per 100,000
Solid matter in solution	30.10
Free and saline ammonia	Nil.
Albuminoid ammonia	0.004
Oxygen consumed in 4 hours at 80° F.	0.025
Nitrites	Nil.
Nitrates	0.31
Combined Chlorine	1.25
Alkalinity (calculated as Calcium carbonate)	22.5
Dissolved oxygen	1.1
Dissolved carbon dioxide	0.4
Silica	0.27

In order to simulate natural conditions Sodium Chloride was added to this water in sufficient quantities to give a chlorine content of 19 per

1000 — an artificial seawater was thus obtained in which oxygen would have approximately the same degree of solubility as it would have in ordinary seawater. In order to remove any possibility of minute organisms and decaying organic matter having any effect upon the oxygen-absorbing power of the water this was boiled and filtered before use.

Steam was bubbled through the water in the aspirator bottle until it reached a temperature of 60° C. (higher temperatures were not used on account of the fear of cracking the aspirator bottles). When this temperature was reached a rubber stopper with a long narrow-bore glass tube connected to a large glass funnel was inserted in the neck of the aspirator bottle. The tube and funnel were then filled with hot artificial seawater (60° C.) and a layer of medicinal paraffin a half inch in thickness was floated upon the surface of the water in the funnel. Fig. 2 will give an idea of the arrangement.

The apparatus was then left overnight in order to allow its contents to cool and assume room temperature. The narrow-bore glass tube and the thick layer of medicinal paraffin allowed the sub-saturated warm water to cool and contract without absorbing much oxygen from the air. This arrangement of obtaining water sub-saturated with oxygen was found more convenient than allowing the water to cool in an oxygen-free atmosphere obtained by passing air through alkaline pyrogallic acid.

Sub-saturated samples were also obtained by placing filtered and boiled artificial seawater in a pressure flask and agitating this water under a reduced pressure obtained by means of an exhausting pump, but the majority of the sub-saturated samples were obtained by the first method.

When a suitable sample of sub-saturated water was obtained the funnel and tube were removed and water was run out of the tap at the bottom of the aspirator bottle until the water level was 5 inches below the constricted part of the neck of the bottle. Oil was then floated upon the surface of the water and samples were abstracted from the tap at regular intervals. The oxygen-content of these samples was obtained by WINKLER's method. As it has been proved by ADENEY and his co-workers that oxygen "streams" very slowly in water, in order to make certain that each sample was truly representative of the whole, the contents of the bottle were gently agitated at frequent intervals by means of the glass rod seen in the sketch of the apparatus. This frequent agitation was only carried out during the first 6 or 8 hours of the experiment and for 2 hours before abstracting the last sample, no stirring was done during the night. The results of these experiments are given below:—

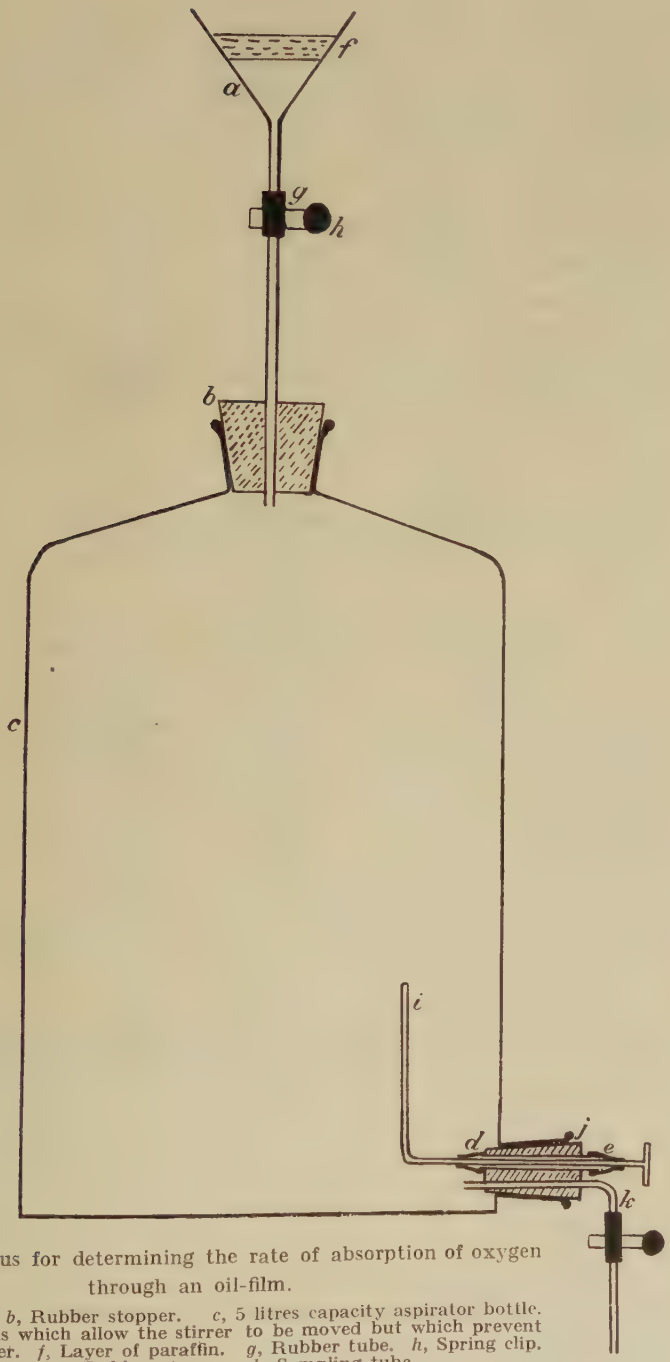

Fig. 2. Apparatus for determining the rate of absorption of oxygen through an oil-film.

a, Glass funnel. *b*, Rubber stopper. *c*, 5 litres capacity aspirator bottle. *d-e*, Rubber glands which allow the stirrer to be moved but which prevent the escape of water. *f*, Layer of paraffin. *g*, Rubber tube. *h*, Spring clip. *i*, Stirrer. *j*, Rubber stopper. *k*, Sampling tube.

Gas Oil.

One drop of oil was floated on the surface of the water. The estimated thickness of the film was 0.00017635 centimetres. On analysis the following amounts of oxygen were found:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Sample taken at start	0.09	13.0° C.	10.3 %
2 hours later.....	0.11	13.0° C.	12.6 %
4 hours later.....	0.153	13.5° C.	17.8 %
6 hours later.....	0.196	13.5° C.	22.8 %
8 hours later.....	0.22	13.5° C.	25.6 %
26 hours later.....	0.799	13.0° C.	91.8 %

In a control experiment with a sub-saturated sample of water with no oil-film the rate of absorption of oxygen was:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
At start of experiment.....	0.12	13.0° C.	13.8 %
2 hours later.....	0.29	13.0° C.	33.3 %
4 hours later.....	0.43	13.5° C.	50.0 %
6 hours later.....	0.53	13.5° C.	61.6 %
8 hours later.....	0.60	13.5° C.	69.8 %
26 hours later.....	0.81	13.0° C.	93.1 %

Diesel Oil.

One drop of Diesel oil on the surface of the water (the estimated thickness of the film was 0.00017635 centimetres) allowed oxygen to diffuse through at the following rates:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
At start of experiment.....	0.53	13.5° C.	61.6 %
2 hours later.....	0.64	13.5° C.	74.4 %
4 hours later.....	0.67	14.0° C.	78.7 %
6 hours later.....	0.72	14.0° C.	84.7 %
24 hours later.....	0.86	13.0° C.	98.8 %

The control experiment absorbed oxygen at the following rate:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.48	13.5° C.	55.8 %
2 hours later.....	0.60	13.5° C.	69.8 %
4 hours later.....	0.73	14.0° C.	85.8 %
6 hours later.....	0.82	14.0° C.	96.5 %
24 hours later.....	0.86	13.0° C.	98.8 %

Fifteen drops of Diesel Oil were floated on the surface giving a film of an estimated thickness of 0.00266 centimetres. Oxygen was absorbed at the following rate:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.357	13.0° C.	41.0 %
3 hours later.....	0.417	15.0° C.	49.6 %
24 hours later.....	0.502	14.0 °C.	59.0 %

The control experiment with sub-saturated water but no oil-film gave the following results:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.476	13.0° C.	54.7 %
3 hours later.....	0.647	15.0° C.	77.0 %
24 hours later.....	0.802	14.0° C.	94.3 %

It will be observed that the film caused by 15 drops of oil caused a perceptible slowing down of the rate of absorption of oxygen, thus:—

	3 hours	24 hours
Film-free sample absorbed.....	0.171 grams	0.426 grams
Oil-film sample absorbed	0.06 —	0.145 —

It should be noted that the oil-film sample contained less oxygen than the control at the start of the experiment; it was therefore more avid for oxygen and should have absorbed it at a greater rate.

600 Seconds Oil.

One drop of oil was floated upon the surface giving a film of an estimated thickness of 0.00017635 cm., the oxygen content of the samples is given below:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.578	14° C.	68.0 %
2 hours later.....	0.647	14° C.	76.2 %
4 hours later.....	0.647	14° C.	76.2 %
6 hours later.....	0.68	15° C.	81.0 %
8 hours later.....	0.72	15° C.	85.7 %
24 hours later.....	0.834	14° C.	98.1 %

The control experiment gave the following results:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.61	14° C.	71.7 %
2 hours later.....	0.74	14° C.	87.0 %
4 hours later.....	0.78	14° C.	91.7 %
6 hours later.....	0.80	15° C.	95.2 %
24 hours later.....	0.84	14° C.	98.7 %

Another set of experiments with a sample of 600 Seconds Oil which had been exposed to air and sunlight for six weeks gave the following results:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.638	15° C.	76.0 %
2 hours later.....	0.638	15° C.	76.0 %
4 hours later.....	0.646	16° C.	78.8 %
6 hours later.....	0.655	16° C.	79.9 %
8 hours later.....	0.663	16° C.	80.8 %
24 hours later.....	0.808	14° C.	95.1 %

No control experiment was done in this above experiment.

1500 Seconds Oil.

One drop of oil was floated upon the surface, this gave a film of an estimated thickness of 0.00017635 cm. The rate of oxygen absorption is given below:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.614	15.0° C.	73.1 %
2 hours later.....	0.65	15.0° C.	77.4 %
4 hours later.....	0.7	15.5° C.	84.3 %
6 hours later.....	0.72	15.5° C.	86.8 %
8 hours later.....	0.77	15.0° C.	91.7 %
24 hours later.....	0.79	15.0° C.	94.0 %

The control experiment gave the following results:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.57	15.0° C.	67.8 %
2 hours later.....	0.72	15.0° C.	85.7 %
4 hours later.....	0.8	15.5° C.	96.4 %
6 hours later.....	0.80	15.0° C.	95.2 %
8 hours later.....	0.81	15.0° C.	96.4 %
24 hours later.....	0.83	15.0° C.	98.8 %

It might be of interest to compare these figures with those obtained with a layer of ordinary paraffin or kerosene one millimetre in thickness.

Paraffin (ordinary commercial).

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.37	15.0° C.	44.0 %
2 hours later.....	0.37	15.0° C.	44.0 %
4 hours later.....	0.38	15.0° C.	45.2 %
6 hours later.....	0.38	15.5° C.	45.8 %
8 hours later.....	0.43	15.0° C.	51.2 %
24 hours later.....	0.75	15.0° C.	89.3 %

RATE OF ABSORPTION THROUGH THIN OIL-FILMS.

All these experiments have dealt with comparatively thick films of about 0.000176 centimetres in thickness. It will now be necessary to examine the rate at which oxygen can penetrate through much thinner films.

The following method was adopted for obtaining a film of less than 1/500,000th of a centimetre in thickness. A tube of 2 centimetres internal diameter was fitted with a cork through which a long wire (16 s. w. g.) was fitted. Fig. 3 will give an idea of the arrangement. In order to obtain a very thin film one drop of oil was first spread on the surface of water in one of the 5 litre aspirator bottles. With the cork pushed out the tube was lowered a few centimetres into the water and in doing so it enclosed a little patch of oil of 3.14 square centimetres in area. The cork was then pulled into the aperture of the tube thus trapping some of the water and a minute quantity of oil. This oil was transferred to the surface of the water in another aspirator bottle where tests on oxygen absorption were carried out.

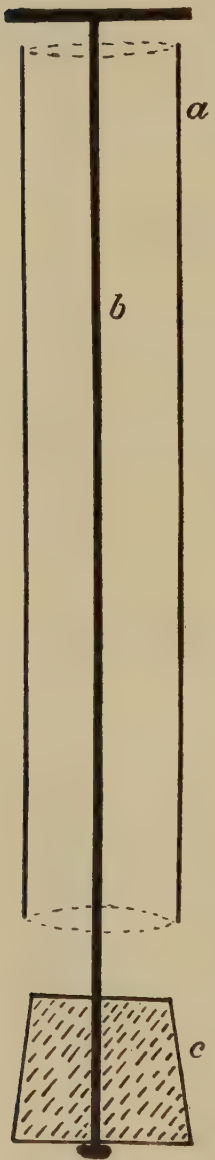

Fig. 3.
Device for obtaining a minute quantity of oil.
a, Open-ended glass tube.
b, Stout wire.
c, Rubber Stopper.

In all the tests carried out with thin films no marked slowing down in the rate of absorption of oxygen could be detected. The results of these experiments are given below:—

Gas Oil.

Absorption of oxygen through a film 0.00000195 cm. thick.

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment	0.58	14° C.	68.2 %
2 hours later.....	0.70	15° C.	83.3 %
4 hours later.....	0.77	15° C.	91.7 %
6 hours later	0.82	15° C.	97.6 %

The control experiment gave:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment	0.5	14° C.	58.8 %
2 hours later	0.63	15° C.	74.9 %
4 hours later	0.75	15° C.	89.3 %
6 hours later	0.78	15° C.	92.8 %

Diesel Oil.

Absorption of oxygen through a film 0.00000195 centimetres in thickness:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.47	14.0° C.	55.3 %
2 hours later.....	0.61	14.5° C.	72.1 %
4 hours later.....	0.71	14.5° C.	84.0 %
6 hours later.....	0.77	14.0° C.	90.5 %

The control experiment gave:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.47	14.0° C.	55.3 %
2 hours later.....	0.60	14.5° C.	71.0 %
4 hours later.....	0.73	14.5° C.	86.3 %
6 hours later.....	0.80	14.0° C.	94.1 %

600 Seconds Oil.

Absorption of oxygen through a film 0.00000195 centimetres in thickness:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.61	15° C.	72.6 %
2 hours later.....	0.72	16° C.	87.8 %
4 hours later.....	0.80	16° C.	97.5 %
6 hours later.....	0.82	16° C.	100.0 %

The control experiment gave:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment.....	0.59	15° C.	70.2 %
2 hours later.....	0.71	16° C.	86.5 %
4 hours later.....	0.79	16° C.	96.3 %
6 hours later.....	0.81	16° C.	98.7 %

1500 Seconds Oil.

Absorption of oxygen through a film 0.00000195 centimetres in thickness:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment	0.49	16.0° C.	59.8 %
2 hours later	0.58	16.5° C.	71.2 %
4 hours later	0.70	16.5° C.	85.9 %
6 hours later	0.82	16.0° C.	100.0 %

The control experiment gave:—

Time sample was taken	Oxygen in parts per 100,000	Temperature	Approximate Percentage saturation
Start of experiment	0.5	16.0° C.	61.0 %
2 hours later	0.62	16.5° C.	76.0 %
4 hours later	0.76	16.5° C.	93.3 %
6 hours later	0.80	16.0° C.	97.5 %

EFFECT OF AGITATION UPON THE RATE OF ABSORPTION OF OXYGEN THROUGH OIL-FILMS.

In all the foregoing experiments the agitation used in order to mix the contents of the aspirator bottles was very slight. The sea, however, is constantly being agitated by wind, wave and tide. Experiments were, therefore, necessary in order to determine the effect of agitation upon the rate of absorption of oxygen through oil-films.

The following method was adopted:—

A drop of oil was floated upon the surface of a sub-saturated sample of water in a large aspirator bottle. A sample of this water was abstracted and the dissolved oxygen present was determined by Winkler's method.

The aspirator bottle was then placed upon a block of wood and rocked from side to side for two minutes. The number of oscillations was at the rate of 20 per minute and the distance of each movement (from the vertical) about six inches. At the end of the rocking movement a sample of water was abstracted and its oxygen content was determined.

The effect of the agitation upon the rate of absorption of oxygen is given below:—

Oil.	Oxygen in parts per 100,000	
	Before agitation	After agitation
Gas Oil	0.63	0.75
Diesel Oil	0.58	0.7
600 Seconds Oil	0.60	0.7
1500 Seconds Oil	0.53	0.63

THE EFFECT OF OILS UPON AQUATIC LIFE.

A number of experiments have been carried out in order to determine the degree of toxicity of oils.

Stephen has found that plaice eggs develop normally in water covered with a film of paraffin 0.03 millimetres in thickness. Pelagic larvae such as plaice and flounders were adversely affected under the same conditions. Copepods and the Cypris stage of the barnacle were unaffected as long as they did not come into contact with the oil-film but were killed on coming into contact with it.

Weigelt found that fish completely disappeared from pools and lakes into which mineral oil had been discharged. The same worker states that ulcerations and attacks of disease follow exposure to petroleum.

According to Thomas the emulsions formed from a petroleum distillate and from a light fuel-oil coated the gill membranes of fish and caused death.

Seydel states that Russian workers have proved that the toxic substance in Russian petroleum is hexahydrobenzoic acid ($C_6H_{11}CO \cdot CH$).

Rushton and Jee found that fuel-oil adversely affected salmon fry and tadpoles but had little effect on Daphnia, molluscs of the genera Planorbis and Limnea, leeches and caddis larvae. Plants, however, were adversely affected, particularly floating forms such as Liverwort (*Riccia natans*) and Duckweed (*Lemna trisulca*). It was observed that certain forms of plant-life appeared to recover from the bad effects of exposure to fuel-oil after six months. Fuel-oil painted on the gills of trout had no effect but an extract of fuel-oil had a slight toxic effect. Mussels and oysters were apparently unharmed by contact with fuel-oil.

Orton found that lubricating oil from a wreck had little effect on mussels and young limpets (Patella). He also observed pollack, gobies and smelts swimming about under a film of the oil and a shoal of the copepod *Calanus finmarchicus*, whose presence is generally regarded as indicative of clean water, was noticed close to the oil-covered side of the wreck. In an experiment Orton found numbers of the marine scavenger, the polychaete Ophryotrocha, feeding upon the scum formed by the lengthy exposure of a petroleum residue to air and water. In general, Orton is of the opinion that the oils discharged at sea are comparatively harmless and that there is little evidence that shore organisms — with the exception of birds — are killed by being smothered with oil.

Jee and Roberts found that freshwater shrimps (*Gammarus pulex*) were killed by contact with fuel-oil and that caddis larvae and freshwater shrimps were killed by immersion in a fuel-oil extract.

LEENHARDT has experimented with mussels (*Mytilus galloprovincialis*), Portuguese oysters (*Gryphea angulata*) and Oysters (*Ostrea edulis*). He found that there was some soluble substance in petroleum which had a slight, but definite, toxic effect upon the shellfish. It is worthy of note that all the organisms seemed equally susceptible. He also arranged his aquaria so that the rise and fall of the tide could be simulated thus drying out the shellfish periodically and exposing them to direct contact with the oil-film. It was found that, under these conditions, the mortality did not exceed that in the tanks where the shellfish did not come into contact with the oil.

ELMHIRST found that *Purpura*, *Serpula*, *Ascidia*, *Anthozoa* and *Mollusca*, *Amoeba* sp., *Oxyrrhis marina*, Duj., *Diophrys* sp., and *Bodo* sp., were unaffected by fuel-oil. Planktonic organisms were killed when they came into contact with the oil but otherwise they lived for several days; *Ecchinus esculentus* and the ova of *Asterias* were slightly affected.

It has already been pointed out that oils might poison fish in two ways:—

1) The oils might contain soluble toxins.
2) Emulsified oils might affect fish adversely.

The experiments which will now be described are intended to show:—

1) Whether soluble toxins are present or not.
2) Whether there is any difference in toxicity between filtered and unfiltered oils, i. e. whether an emulsion has any effect.

Extracts were made of each oil by shaking 100 ccs. of oil with 2000 ccs. of boiled and filtered River Itchen water. In order to gain an extract such as would be likely to be met with at sea where the oil films would be exposed for lengthy periods to air, light etc. the preparation of the samples took 3 months. Twice a week the samples were shaken vigorously and the stoppers were removed periodically to allow fresh air to enter the bottles. The bottles were stored in a place exposed to light.

The extracts for the tests were siphoned off in order to prevent too much oil floating upon the surface of the water in the experimental troughs. In this siphoning process small quantities of oil managed to get into the experimental troughs. These experimental troughs were 50 cms. in length by 14 cms. in breadth. The test solutions filled these troughs to a depth of 3 cms. After the unfiltered extracts had been tested upon fish they were filtered through WHATMAN's Filter Paper No. 1 — each filtration was carried out as rapidly as possible by using five or six filters at once. Suction pumps were not used.

These methods of filtration were used in order to limit escape of the volatile oils.

It will be noticed that these tests were performed with freshwater fish. After repeated attempts it was found impossible to use sea fish as these proved to be too variable in their reactions, presumably for the reason that sea fish cannot stand even small quantities of free Carbon Dioxide which gas would, as the experiments proceeded, tend to form in the experimental troughs.

PHYSIOLOGICAL TESTS WITH GAS OIL.

Unfiltered extract.

Two 3-inch brown trout (S. Fario) were immersed in the extract. They began to show signs of distress almost immediately, as instanced by nervous darts up and down the trough and by convulsive movements of the gills.

In 1 minute 55 seconds, one trout became helpless and turned turtle, the other trout turned turtle in 2 minutes 10 seconds.

Both fish on removal to fresh running water recovered from the bad effects of the immersion.

Filtered extract.

Two 3-inch brown trout were immersed in the filtered extract. They showed signs of distress almost immediately. One trout lost equilibrium in 6 minutes, the other in 6 minutes 45 seconds. On removal to fresh running water both fish recovered.

Another experiment was carried out with the filtered extract diluted 1 in 2 by the addition of one volume R. Itchen water. Two trout were immersed in this dilution and showed distress; they lost equilibrium in the following times:—

One turned turtle in 48 minutes and the other in 52 minutes 20 seconds.

Both fish recovered on removal to fresh running water.

PHYSIOLOGICAL TEST WITH DIESEL OIL.

Unfiltered extract.

Four 3-inch brown trout were immersed in the extract. They immediately showed signs of distress and lost equilibrium in the following times:—

One lost equilibrium in 3 minutes 35 seconds.

— — — - 4 — 45 —

Filtered extract.

Two 3-inch brown trout were immersed in the extract; they showed signs of distress and lost equilibrium in the following times:—

One fish lost equilibrium in 4 minutes 55 secs.

— — — — - 6 — —

The filtered extract was diluted by the addition of one volume of River Itchen water. Two 3-inch trout were immersed in this with the following results:—

One fish turned turtle in 23 minutes 45 secs.

— — — — - 23 — 55 —

In the above tests all the fish recovered on removal to fresh running water.

PHYSIOLOGICAL TESTS WITH "600 SECONDS" OIL.

Unfiltered extract.

Two 3-inch brown trout were immersed in the solution; they showed signs of distress and lost equilibrium in the following times:—

One lost equilibrium in 16 minutes.

— — — - 17 — 30 seconds.

Both fish recovered when removed to fresh running water.

Filtered extract.

Two trout were immersed in this solution, one trout lost equilibrium in exactly 3 hours but recovered on removal to fresh running water, the other fish although badly affected survived six hours immersion but subsequently died.

PHYSIOLOGICAL TESTS WITH "1500 SECONDS" OIL.

Unfiltered extract.

Two 3-inch brown trout were immersed in the solution; they immediately showed signs of distress and lost equilibrium in the following times:—

One lost equilibrium in 17 minutes 53 seconds.

— — — - 26 — 30 —

Both fish recovered on removal to fresh running water.

Filtered extract.

Two 3-inch brown trout showed no distress in 2 hours in the filtered extract. In another experiment two 3-inch brown trout were unaffected by an immersion of 6 hours duration.

It will be seen that all the oils were markedly toxic in the unfiltered condition. Three of the oils, Diesel Oil, Gas Oil and "600 Seconds" Oil were toxic in the filtered condition but to a less extent than when unfiltered. The conclusion may be drawn that fuel-oils contain soluble toxic substances and also that emulsified oils have an adverse effect upon fish.

The soluble toxic substances appear to be of a phenolic nature as, when tested with diazotised sulphanilic acid (Fox and Gauge) they give a distinctive reddish-yellow coloration. The colours obtained by adding diazotised sulphanilic acid to the filtered extracts corresponded to the following quantities of Tar Acids:—

Gas Oil	1 part Tar Acids per 100,000.
Diesel Oil	.9 parts Tar Acids per 100,000.
"600 Seconds" Oil	.75 — — — - —
"1500 Seconds" Oil	.25 — — — - —

The question now arises as to the possible effect of these soluble toxins and emulsions upon marine life. The first point to be decided is the quantity of toxins and emulsions likely to be met with at sea. The quantity of emulsions would be difficult, if not impossible, to estimate as the factors governing the formation of emulsions are numerous and very variable.

In view of the thinness of an oil-film it is obvious that the quantity of a soluble toxic substance likely to be met with at sea would be very minute. It is estimated that the concentration of a toxin under an oil-film would be about 10^{-8} of a gram per litre — a quantity too minute to detect analytically and unlikely to exercise any harmful effect.

PHYSIOLOGICAL TESTS ON EXTRACTS WHICH HAD BEEN EXPOSED TO THE AIR

There is a likelihood that oil-fuel extracts might lose their toxicity on being exposed to the air for some time. If such were the case the loss in toxicity might be due to the loss of toxic volatile substances or to the oxidation of the toxic substances.

In order to test the effect of exposure to air, the filtered extracts, which had already been used, were left exposed, in the experimental troughs, for 10 days. At the end of this time brown trout were tested in the solutions and the effects of these are summarised below:—

Gas Oil.

Dilution 1 in 2.

One trout lost equilibrium in 1 hour 15 minutes.

— — — — - 3 hours 30 minutes.

Both fish recovered on removal to fresh, running water.

Diesel Oil.

Dilution 1 in 2.

Both trout, although obviously uneasy as instanced by gulping, etc., survived a six hours immersion and recovered their health and spirits in fresh, running water.

600 Seconds Oil.

Dilution — Undiluted.

One trout lost equilibrium in 3 hours 45 minutes.

— — — — - 4 — 35 —

Both fish recovered on removal to fresh, running water.

1500 Seconds Oil.

Dilution — Undiluted.

Both fish lost equilibrium in 3 hours 42 minutes but recovered in fresh, running water.

For purpose of comparison the times at which the fish turned turtle are summarised below:—

Gas Oil.

Undiluted extract.

	Unfiltered	*Filtered*
(1)	1 min. 55 secs.	6 mins.
(2)	2 mins. 10 secs.	6 mins. 45 secs.

Diluted 1 in 2.

	Filtered	*Exposed*
(1)	48 mins.	1 hour 15 mins.
(2)	52 mins. 20 secs.	3 hours 30 mins.

Diesel Oil.

Undiluted extract.

	Unfiltered	*Filtered*
(1)	3 mins. 35 secs.	4 mins. 55 secs.
(2)	4 mins. 45 secs.	6 mins.

Diluted 1 in 2.

	Filtered	*Exposed*
(1)	23 mins. 45 secs.	Both survived a six hours
(2)	23 mins. 55 secs.	immersion.

600 Seconds Oil.

Undiluted extract.

	Unfiltered	*Filtered*	*Exposed*
(1)	16 mins.	3 hours	3 hours 45 mins.
(2)	17 mins. 30 secs.	Survived 6 hrs. subsequently died	4 hours 35 mins.

1500 Seconds Oil.

Undiluted extract.

	Unfiltered	*Filtered*	*Exposed*
(1)	17 mins. 53 secs.	Both survived 6 hours	3 hours 42 mins.
(2)	26 mins. 30 secs.	immersion	3 hours 42 mins.

Summary.

Gas Oil, Diesel Oil, 600 Seconds Oil and 1500 Seconds Oil were used in the experiments. These oils represent the four types most commonly used at sea.

It was found that:—

1) Oil-films slow down absorption of oxygen from air, but in very thin films, likely to be met with at sea, no slowing down was appreciable.
2) Agitation, such as would be met with at sea, markedly increases the rate of absorption through an oil-film.
3) A simple method is suggested for checking spread of oil-fuel in restricted waters.
4) All the oils tested were found to be toxic to fish. It is believed that this toxicity is due to both soluble toxic substances and to emulsions.
5) On exposure to air, extracts of Gas Oil and Diesel Oil lose much of their toxicity. An extract of 600 Secs. Oil was unaffected by exposure but an extract of 1500 Secs. Oil was found to be more toxic.
6) Oil-films do not prevent the growth of freshwater plants.

General.

The adverse effects of fuel oils on fish, shell-fish, plankton and plants, are not very marked, but these oils are the cause of death of countless sea-birds.

It is not contended, however, that oil-pollution in its effects upon marine life need cause no anxiety. On the contrary, it is felt that it will, if unchecked, become a menace in the future.

Enormous quantities of asphalts gain access to the sea through discharges of ballast-water. Asphalts tend to concentrate into masses which ultimately drift inshore into sheltered bays and the like.

Even if oil-discharges were made many hundreds of miles from land the chemical inertness of the asphalts is such that they would float, without physical change, for many months. In this time the oil-patches might drift great distances.

At present these quantities of asphalt are small but it is likely that in 20 years time most ships will use fuel-oil and the quantities would no longer be negligible. It should be pointed out, however, that the probable fuel-oil of the future, Diesel Oil, contains relatively little asphalt as compared with the oils used for steam-raising.

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Note.

Frequency Curves and Herring Investigation.

Fishery investigators do not usually read each others' papers. So it will be quite useful to draw attention to Dr. EINAR LEA's criticism of Prof. D'ARCY THOMPSON's criticism of the method of finding the age of a herring by counting the no. of rings on its scales. (Rept. Norwegian Fishery and Mar. Investns. Vol. 3, no. 4, Bergen 1924). Prof. THOMPSON and Miss SHERIFF had found that such a series as the following:—

no. of rings on a scale:	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16
frequency of each no. of rings on a scale:	5, 32, 46, 49, 51, 40, 29, 18, 11, 5, 2, 1, 1

could be treated by the methods of KARL PEARSON's "Generalised Probability Curve". Thus the crude data of the second line could be replaced by data calculated by using the "Type I" of Pearson's curves. Now if we know no more about the matter than this we might conclude that the herrings in the population from which this sample was taken ought to have had about 7 rings on their scales; that they may really have anything from 4 to 16 rings and that the differences from the proper number of 7 rings are due to variability. Thus the "organic character", no. of rings, is a variable one and it is the result of "chance", that is the summation of a number of causes which are not quite equal to each other, not quite independent of each other and which so operate as to give a curve which is asymmetrical and may be highly asymmetrical. That appears to be all that mathematical analysis of the data tells us.

Dr. LEA writes quite a long paper to show that Prof. THOMPSON and Miss SHERIFF are wrong and that the variability of the no. of rings on a herring scale is not due to "chance" in the ordinary sense. Of course it is due to chance in the sense in which KARL PEARSON used the term. That is, instead of a large number of small, independent causes of variation there are now a few correlated causes and there is one cause which is much greater in its effect than any of the others: this predominant cause is the age of the fish.

Of course Dr. LEA is quite right but I wish to point out that my colleagues, W. BIRTWISTLE and H. MABEL LEWIS made just the same criticism of Prof. THOMPSON's argument in 1922 (Ann. Rept. no. 31, Lancashire Sea-Fish. Laby. Liverpool, 1923, pp. 74—81). There they decomposed a calculated Pearson Type III curve into 4 normal (Type VI) curves. The material was known to be heterogeneous and yet the theoretic curve "fitted" it with a fair degree of probability.

But long before this Prof. KARL PEARSON himself showed (Biometrika vol. 10, pp. 85—143) that an empirical frequency distribution could generally be represented by a theoretical frequency curve and that the latter curve could generally be represented by several normal curves. Thus (in an analogous problem) he showed that a number of species, or races, of Trypanosomas, classified according to their modal lengths were, most probably, only mixtures, in varying proportions, of the races, *T. majus* and *T. minus*. The fact is, it is unwise to use any of the Pearson statistical methods without taking due account of all the reservations and refinements of those methods made by PEARSON and his pupils.

And, one may suggest, it is curious that there should not be some simple biological proof that a herring adds a new ring to its scales every year rather than these indirect mathematical arguments for and against the matter. J. J.

Reviews.

HARRY M. KYLE. The Biology of Fishes. pp. XVI + 396; XVII plates and 77 figures in the text. London, Sidgwick & Jackson, 1926. Price 16/- net.

Former colleagues and friends of Dr. KYLE will be interested in this book: the fruit of a long experience of fishery investigation, and an exceptional aquaintance with the literature of ichthyology. It is particularly well done and even with regard to very recent researches it is "up to date". The style is agreeable and simple so that readers who may have only a very limited knowledge of biology will be able to read it with advantage. On the other hand many of us who have had to restrict ourselves to what the author calls the "microscopic methods necessary for the exact determination of details" of fishery questions will find it advantageous (and really quite interesting) to survey the whole field of knowledge with respect to the biology of fishes. For this purpose Dr. KYLE's book is just the thing.

For there is not an excess of morphology, or of systematics, or of the tiresome accounts of life histories and all that sort of things. The ordinary structure of fishes and its significance; the curious adaptations and regulations of structure and functioning; the natural history, habits and mentality of living fishes; their distribution now and in the past are subjects that are all very well done and with a sense of balance that has come as the result of a really extensive knowledge of the whole subject. There is a chapter on the investigations that have been made with respect to the biology of the great sea fisheries and this is also well done though the subject is so interesting to the general reader that much more space might with advantage have been given to it. On the whole the author does not regard the condition of the deepsea fisheries with anxiety but the question of the exploitation of the sea is only treated slightly.

There are some curious expressions here and there in the book that may puzzle some readers. "Blood-pressure" (on p. 23 and elsewhere) means osmotic pressure. "Radiant energy" is made to include not only the emission of light by luminous organs but also intelligence and feeling. We are told (in chap. XIV) that the fishes may be "in league with elemental forces powers of darkness, which man is only beginning to discover" and we are directed to chapter VIII for the demonstration of this statement. But Chap. VIII contains only accounts of such matters as Dr. SCHMIDT's studies on variability and Prof. D'ARCY THOMPSON's conception of distorted frames of reference.

The book is cordially recommended. It is quite the best general account of the biology of fishes that has yet been published in the English language.

J. J.

A. C. Johansen. On the Diurnal Vertical Movements of Young of some Fishes in Danish Waters. Meddelelser fra Kommissionen for Havundersøgelser. Serie: Fiskeri; Bd. VIII, Nr. 2, 1925.

In April 1925 the "Dana" carried out a cruise in the Kattegat, Belt Sea and western part of the Baltic. This was primarily for the study of the distribution and frequency of the young of the winter-spawning herring and of the cod.

In the course of the collecting it became obvious that more young fish were being caught at night than in the daytime in the upper water layers. In view of this a systematic series of hauls was undertaken throughout the 24 hours on April 20th—21st, 1925, in the Southern Kattegat, in water about 25 metres deep; it is chiefly with the results of this collection, together with a comparison of other day and night hauls, that Dr. Johansen deals in this paper. Collecting was carried out with a stramin ringtrawl (2 metres at mouth and 7 metres long) fished at the surface and at an intermediate depth that was estimated as being at about 16 metres. The hauls were taken at regular two hour intervals throughout the 24 hours. Vertical hauls were also made with the Hensen net from 10 metres to the surface and from the bottom to the surface.

The figures, although rather low for most species, show an increase in the numbers of fish, and also in the numbers of species, taken at night over the daytime catches. There were two species that did not appear to conform with this, *Gadus callarias* and *Drepanopsetta platessoides*. From the fact that for most species an increase in numbers was shewn at night both at the surface and in the intermediate layer the author suggests that the majority of larvae kept down below the 16 metre level in the day-time.

The results of this serial collection are compared with those of the other day and night hauls taken throughout the cruise and they show a striking agreement. The average catch of specimens for all the species observed was larger in the night hauls than in the day hauls in the upper layers; and the average number of species caught per hour was 10 in the night hauls, while in the day-time it was only 3. As a result Dr. Johansen makes the important statement that when comparing catches of the ringtrawl from the upper water layers in different areas, or at the same place at different times, the time of day at which the hauls were made must be taken into consideration.

The possibility of the young fish escaping the net in the day-time so that net collections may give a misleading picture is very briefly discussed. The decision arrived at is that "It may be doubtful whether any conclusions can be drawn — — — — as to the vertical migrations on the part of the larger, rapidly moving larvae; it seems justified, however, in the case of the tiny larvae". One would have liked to see this statement, in which the word "larvae" embraces both stages known by some as "larvae" and "post-larvae", expanded to explain what is meant exactly by the "larger rapidly moving" and the "tiny" larvae.

A short account of the diurnal variation in the volume of the plankton catches made by the Hensen net is given showing that there was a marked

increase in the amount of zoo-plankton, and also apparently of phyto-plankton, caught at night. Mention is made of some of the findings of previous workers on diurnal changes in the vertical distribution of plankton organisms; such discussion seems very much to emphasize the point that far more observations in the field are required and shows how limited our knowledge really is about the behaviour and distribution of plankton organisms in the sea.

It is unfortunate that Dr. JOHANSEN did not take hauls from more depths in this series so as to throw some light on the actual vertical distribution of the young fish by day, and to what extent this distribution changed at night; it is only just to say however that in this respect he was greatly handicapped by the lack of some graphic depth recording instrument to show the actual fishing depths: a convenient instrument for work of this kind is badly needed. F. S. R.

A. P. ORR. The Nitrite Content of Sea-Water. Journal of the Marine Biological Association of the U. K., N. S., XIV, pp. 55—61, (1926).

The need for accurate determination of the nitrogen-content of the sea, and its variations, becomes greater as the importance of this element in the algal metabolism is increasingly realised. The small amount of nitrogen compounds normally present, and their somewhat unstable character, render the determination a matter of some difficulty, and it is with satisfaction that we note the number of workers who are now seriously tackling the problem, especially since it involves a great deal of preliminary experimental work, and the elimination of faulty methods, before results of definite value can be obtained.

In the present paper, Mr. ORR, of the Millport Marine Station, reports having given careful trial to the gasovolumetric method recently proposed by GAD-ANDRESEN (Publ. de Circ., No. 82, 1923), for the estimation of the nitrogenous compounds in sea-water, and concludes that, with regard to nitrites, the method is unsuitable, since the sulphuric acid, or sulphur dioxide solution, added as a preservative to the sea-water samples when collected, upsets the nitrite-nitrate relation. It should be noted, however, that GAD-ANDRESEN does not claim that his method affords a separate estimation of these compounds, nor does he mention having analysed a series of samples preserved in the manner indicated. Mr. ORR finally adopts a slight modification of the well-known Griess-Ilosvay method, already applied to sea-water by BUCH. The method, involving as it does the addition of a measured volume of a ready-mixed reagent to a known volume of the sea-water and comparing the colour produced, in Hehner tubes, with that obtained from a standard nitrite solution under identical conditions, is one readily capable of application, even in a primitive laboratory on shipboard. It should, therefore, find general application whenever it is possible to examine the samples, as was done by the author, within a few hours of collection. However desirable this may be, there is still room for a method which is applicable to stored samples, or for a preservative which is compatible with a variety of subsequent determinations.

Applying the method, the author finds, in the Clyde Sea Area, during the summer months, a surface-content of 0.001 0.003 mg. nitrite-nitrogen per litre; the amount becomes greater with increasing depth, and reaches 0.009 mg. per litre at one station in 5 fathoms. There are irregularities in the depth-distribution curve which call for further investigation.

A brief, but useful, résumé of the causes, physical and biological, leading to the variation of the nitrite-content of the sea, is appended.

J. R. B.

H. W. Harvey. Nitrate in the Sea. Journal of the Marine Biological Association of the U. K., N. S., XIV, pp. 71—88, (1926).

The author finds that the Denigès test for nitrite and nitrate — the production of a red compound with an acid solution of "reduced strychnine" — is available as a quantitative method when suitably modified, and applied under standard conditions. While ferric salts have been shown by Kolthoff to interfere with the delicacy of the test, the iron present in sea-water is without effect upon the reaction. It is apparently held in some organic combination, which only responds to the tests for the ferric (or ferrous) ion when broken down by vigorous oxidation. Nitrites could only be detected in polluted waters, and it is assumed that the reaction, in the case of open sea and deep water samples, is wholly attributable to nitrate. Directions are given for making up the special reagent, and the technique, involving only the usual laboratory apparatus, is described. Unfortunately for the simplicity of the method, differences in salinity, and certain undefined factors, give rise to variation in the depth of colour produced when samples from different stations or depths, but of equal nitrate-content, are examined. It is not permissible, therefore, to assume that the absolute relation of the nitrate-contents of a number of samples is proportional to their relative depths of colour, and it becomes necessary to determine, for each sample, the colour-increment, measured in arbitrary units, resulting from known additions of nitrate-N_2; the original nitrate-content is then readily determined by extrapolation. The method is not applicable to waters containing any considerable quantity of organic matter, whether in the form of sewage or plankton.

An investigation of the distribution of nitrate-N_2 in the sea, during 1925, reveals several important facts. Definite evidence is adduced to show that deficiency of nitrate is a limiting factor for plant growth in the sea — a view to which the earlier results of Brandt did not lend support. The annual fluctuation of nitrate-N_2 in the surface water of the English Channel, at a point 22 miles S.W. of Plymouth, stands in evident relation to the seasonal phytoplankton curve: from April to September the nitrate-content is practically nil, and at the onset of winter it rises to 70 mg. per cubic metre. The metabolic demands of the spring and early summer diatom-outburst correspond to a depletion of the surface layers, while the autumn is marked by a rapid rise in the nitrate-content at 50 metres, resulting from the breakdown of the dead and sinking organisms. Finally the approach of winter, with a shallowing thermal gradient and more

efficient vertical mixing, results in the return of the nitrate-stores to the sunlit surface waters.

The author was enabled to examine samples of sea-water from the open Atlantic, the Bay of Biscay and the North Sea, and the general conclusion was reached that the nitrate-concentration of the surface-layer is low (0—10 mg. per cubic metre) where there is no upwelling from the deeper waters. The high nitrogen content of the ocean-depths, however, is well illustrated by a series of samples collected by the R. R. S. Discovery, (in Lat. 37°44′ N., Long. 13°21′ W.) at depths down to 3000 metres. From these it would appear that the waters below 500 metres may contain 200—270 mg. per cubic metre, and an interesting, though purely speculative, calculation places the potential nitrate reserves of the great oceans at somewhere about 25×10^{10} metric tons.

In a very useful discussion of the Nitrogen Cycle, the author expresses the belief that, in the open sea, the cycle is a closed one, the proteins of the plant-body passing by various channels, direct and indirect, through ammonium salts and nitrates, back to the living plant, with bacteria as the active agents at every stage of the transformation. While this may be true in general of the open sea, there are unquestionably complicating factors at work in the coastal waters. Here, the cycle can no longer be regarded as a closed one; there are accessions and removals of nitrogenous material of great magnitude — thousands of tons of sewage are poured daily into our seas, a million tons of fish are landed annually at our ports, and 400,000 tons of seaweed are gathered annually from the coasts of western Europe. These figures, perhaps, are trivial in comparison with the waters of the globe, and the results may be purely local in their incidence, but it must not be forgotten that the coastal region is of far greater importance, from the point of view of organic production, than the open ocean.

With these inshore problems in view, and with the rôle and distribution of nitrifying bacteria as yet obscure, the nitrate in the sea still calls for intensive study. We trust that Mr. Harvey will continue his investigation, and furnish us with further data from the region we have indicated.

J. R. B.

W. R. G. Atkins. Seasonal Changes in the Silica Content of Natural Waters in Relation to the Phytoplankton. Journal of the Marine Biological Association of the U. K., N. S., XIV, pp. 89—99, (1926).

Dr. Atkins has now applied to sea-water the method of Diénert and Wandenbulcke (1923) for the estimation of silica, which gave such interesting results, in his hands, in connection with the diatom periodicity in fresh water ponds.

The method consists in the addition of 2 cc. of a 10 per cent. soln. of ammonium molybdate to 100 cc. of the water to be tested, followed by 4 drops of 50 per cent. (vol.) sulphuric acid. This results in the production of a yellow colour, which is conveniently matched against a very dilute solution of picric acid — 0.369 mg. per litre of picric acid giving a depth of tint equal to that given by 0.50 mg. per litre of SiO_2 present

in solution as silicate. With practice, the author has been able to match tints corresponding to as low a concentration of silica as 0.04 mg. per litre, and has ascertained that phosphate, in the amount normally present in sea-water, introduces no appreciable error into the determination. The method is at least as accurate as the gravimetric process, and avoids the risk, inherent in the latter, of solution of silica during concentration.

With a method of such delicacy available, the possibility of solution of the glass of the sample-bottles could not be overlooked, and where long storage is inevitable, coating of the bottles with paraffin-wax is recommended. For periods up to five days, however, in cool weather, the error due to solution of the glass falls within that of the method.

As a result of a large number of analyses, the author concludes that, in general, fresh water has a much higher silica-content than the sea, Plymouth tap-water, for example, containing 3300 mg. per cubic metre throughout the year, while the sea at an English Channel station only held about 220 mg. per cubic metre at the winter maximum. The differing silica-content of fresh and sea-water is well illustrated by a series of samples taken at successive stations seaward of Plymouth Sound, these showing at all seasons a progressive fall in silica as the region of fresh water drainage is left behind.

Dr. Atkins brings forward well-marked evidence of a depletion of the silica-content of the sea, synchronous with the period of rapid diatom-growth, but he is of opinion that, at any rate in the open ocean, lack of silica cannot be regarded as a limiting factor, though this view is subject to the qualification that there may be a minimum concentration of silica, below which the living diatom can no longer abstract the silica necessary for the growth of its envelope.

As in the case of nitrate, the ocean-deeps are vast potential reservoirs of silica — one sample from 3000 metres contained 1200 mg. per cubic metre — and these stores can only become available for plant-life in the upper illuminated zone, when brought thither by upwelling currents.

From determinations by the author on the solubility of laboratory glass in fresh and sea-water, it is evident that hydrogen ion concentration is a very potent factor in the "silico-solvency" of various waters, and when the seasonal variations in silica-content come to be more fully correlated with diatom-growth, the concurrent changes in pH will be numbered among the factors for consideration. J. R. B.

F. S. Russell. The Vertical Distribution of Marine Macroplankton II. The Pelagic Young of Teleostean Fishes in the Daytime in the Plymouth Area, with a Note on the Eggs of certain Species. Journal of the Marine Biological Association of the U. K., N. S. XIV, pp. 101—159, 1926.

In this paper Mr. Russell deals with the young fishes, mainly post-larval, taken in collections made by daylight with a two-metre ring net of stramin, a kind of open canvas, from April to August in 1924 and 1925. Horizontal hauls were made at from four to six different depths at each

of 27 stations the depth of the net at each haul being determined by a depth recording instrument.

Though a very large quantity of plankton must have been collected it was only in the case of less than half of the forty odd species observed that sufficient specimens were present to allow of a definite range being assigned to them. The most plentiful fishes in the collection were the Dragonets *(Callionymus)* and the Gobies *(Gobius)* which between them accounted for about 60 per cent. of the total, the Gobies for some unascertained reason being very abundant in 1924 and comparatively scarce in 1925. Similar fluctuations, though not as marked, were noted in the case of other species. The vertical distributions of several of the more plentiful species, e. g. the Whiting *(Gadus merlangus)*, the Poor Cod *(G. minutus)* the Pollack *(G. pollachius)*, the Dab *(Pleuronectes limanda)* and the Thick-back Sole *(Solea variegata)* are discussed in detail, and it is noted that different species, while showing an extensive vertical distribution, differed markedly and consistently in the depth below the surface at which they became common. The young Pollack for example preferred the layers immediately below the surface, while the Poor Cod were not found in any considerable numbers above 20 metres. The Whiting were intermediate between these two and showed a tendency to descend as the season advanced. Other species again were found indiscriminately from the surface to the greatest depth investigated, about 40 metres.

Observations on fish eggs were also made to determine if any change of depth occurred as development proceeded. No evidence was found of this in the case of Sprat eggs, but in the case of the Pilchard there was some indication that the more advanced stages were relatively scarcer at the surface than in the deeper layers.

Full details are given at the end of the paper of all the stations, with the names of all species of fish taken and their numbers at each depth. It is on detailed observations such as these, repeated so as to compare the varying conditions of different years and different localities, that a sound knowledge of the vertical distribution of young fishes must be based and without this knowledge it would be difficult to recognise at an early stage the fluctuations from year to year which are of such importance in commercial fisheries. G. P. F.

Professor J. Giral. Quelques observations sur l'emploi de l'eau normale en océanographie. Publ. de Circons. No. 90, 1926.

Professor Giral's paper is addressed to the non-chemical oceanographer and is an attack on the normal water of Copenhagen and on the methods of analysis almost universally adopted. He maintains in the first place that titration against the normal water is so inaccurate that the limits of permissible error laid down at Stockholm ought to be increased tenfold from 0.02 $^0/_{00}$ to 0.20 $^0/_{00}$ of chlorine. The chief source of error, he holds, is in the normal water itself; however carefully this is made up in the first instance it dissolves so much chlorine from the glass container in course of time that the content in this is raised by even 0.15. Now,

frankly, this is impossible, and if Professor GIRAL has found normal water seriously in error it has almost certainly been due to fracture of the extreme tip of the sealed end of the tube and consequent evaporation; the present writer has met with more than one such case. Chlorine is not used in glass making except as an accidental impurity in the ingredients; the chlorides of sodium and potassium are volatile at the temperature of the furnace, and what is not volatilized is largely removed in the scum. Tables of analyses of standard glasses do not mention chlorine as present even in traces. KNUDSEN has shown that one batch of normal water increased by 0.000015 in density in 27 months; if the dissolved material had been pure chlorine the error would still have been within the limits. The uncertainty due to the variation in the atomic weights can be avoided as Professor GIRAL himself suggests by referring everything to the Primary Standard and the atomic weights used when it was prepared. The other sources of error are the personal equation and its variability, and large differences between the salinities of the normal water and of the sample. In the experience of the present writer and, he believes, of the majority of oceanographers, personal equation does not amount to as much as 0.02 $^0/_{00}$ Cl provided that the colour vision is good. Large differences of salinity make the use of the bulb burette impossible and so reduce the attainable accuracy considerably, while the consequent differences in the coefficient of expansion add to the difficulties. Fortunately in northern European waters the greatest accuracy is needed in those salinities which do not differ greatly from 35 $^0/_{00}$. Low salinities change so rapidly with time, position and depth that great accuracy in the titrations is not needed. In the Mediterranean and Red Sea the case is entirely otherwise, and a special normal water would be of great value, provided always that its chlorine is determined with reference to the Primary Standard and not independently. New titration tables would of course be necessary.

Professor GIRAL refers also to the want of constancy in the ratios of the components and properties of sea water to one another. It is certain that the ratios are not constant, but it appears to be no less certain that the greater the accuracy with which they can be determined the nearer they approach to constancy for practical oceanographical purposes. The investigations reported in 1910 by RUPPIN have shown that KNUDSEN'S formula for passing from chlorine to density is correct for the northern European waters to 0.01 $^0/_{00}$ Cl while the present writer has found that the difference does not exceed 0.02 $^0/_{00}$ in the surface waters of the Indian Ocean. Compared with the limits of accuracy laid down at Stockholm for chlorine the formula is satisfactory. The determination of the conventional salinity is extremely difficult and KNUDSEN s differences between the observed and calculated values, — 0.002 $^0/_{00}$ to 0.011 $^0/_{00}$ are surprisingly small. Professor GIRAL has found a much wider range, — 0.303 $^0/_{00}$ to 0.027 $^0/_{00}$, but unfortunately he tells us nothing more about the water examined. The ratio of SO_3 to Cl varies widely according to numerous observers, but the errors attaching to its determination in mixtures like sea water have been recognized only during the present century. The figures quoted in RUPPIN'S report show that the ratios found at Kiel, Nancy and Helsingfors were consistent for each laboratory but that there

was a difference from one laboratory to another which was outside the experimental error, from which we may deduce that the ratios are constant but that the methods of determining sulphates are open to improvement. The determination of calcium and magnesium in mixtures of the two is still so defective that no reliance can be placed on their ratios. Professor GIRAL's recommendation with regard to bromine is perhaps open to misconstruction; he would neglect the correction to the equivalent weight of chlorine because it does not reach the second decimal place per thousand. This of course applies only to the calculation of the chlorine from the weight of the silver precipitate; the correction in an average water is about 0.036 $^{0}/_{00}$ and in any case it is made automatically because the normal water and the Tables are founded on titration and not on gravimetric analysis.

Professor GIRAL further recommends that sodium chloride should be substituted for the normal water and that each country should prepare its own solutions. This would mean giving up one of the greatest benefits which the Conseil Permanent has conferred on oceanography, the certainty that all salinities are comparable so far as the skill of the individual observers allows. How great is this benefit anyone who has tried to make critical use of the older determinations will at once allow, and only the most weighty reasons would justify the adoption of the proposal. Professor GIRAL brings forward two chief reasons. The first is that a solution of sodium chloride does not attack glass, a point which has been dealt with already, while the second is that it is readily procurable everywhere in a state of absolute purity. It is hard to agree with the last statement. The removal of the last traces of moisture from it without setting up partial decomposition requires considerable time and skill; according to KNUDSEN drying for 52 hours at 380° C. is necessary. The preparation of the solutions would have to be entrusted to an expert whose time would probably be worth more than the cost of the normal water, and even then the strict comparability of the work done in different countries could be ensured only by an interchange of samples. On the other hand, if the sodium chloride is to be titrated against the normal water, why make a change at all?

Another recommendation is that chlorine should be determined and reported per litre and that the density should also be determined. To substitute grams per litre for the present system is surely a retrograde step; it means giving up the simplest possible description of the water, the ratio of two weights, in favour of a method which requires in addition the introduction of temperature and of the ratio of weight to volume. The determination of density in addition is chiefly a matter of money and skill and if carried out with an error of not more than 0.00001 might give valuable results. But the present is hardly the time to place an additional burden on oceanographers. D. J. M.

JAMES JOHNSTONE. A Study of the Oceans. London. Edward Arnold & Co. Pp. VIII + 215.

In 1923 Professor Johnstone gave us his Introduction to Oceanography; in that work he briefly applied modern knowledge of geophysics

and earth movements in an attempt to sketch the origins of the oceans and the secular changes which they have undergone throughout the course of geological time. His study was of great service in bringing together within the compass of a small volume the results of researches reported upon in a very scattered literature.

The book before us goes much further; it is a substantial treatise whose perusal leaves us with the conviction that the growing library of books dealing with the study of the oceans has received an addition of first rate importance.

In his preface Professor JOHNSTONE refers to the adventurous wanderings of the voyagers of old, and tells us that they really did, to some extent, investigate the physics and biology of the oceans. We are told that there was, however, nearly always the stimulus of a real or ostensible economic or political aim underlying their voyages. These old time mariners did, in their attempts to find sea-routes between different parts of the earth, accumulate knowledge as to the forms and dimensions of the oceans. The discovery of new sea routes with the consequent acquisition of new territory and its exploitation, made the question of balance of power an acute one. Thus "in many interesting ways, scientific geography became mixed up with economic and political affairs, and it is good for the student to have all these aspects of the subject presented to him".

Nowadays the study of geographical science is begun with some notion of the structure of the earth and of its relation to other cosmic bodies. We moderns of necessity know much more of this subject than the ancients; we cannot like them watch the gradual development of our subject. Hence, says the author "the best thing to do is to have clear general ideas about the latest results of investigation".

The book commences therefore with a discussion of the earth's probable origin and of the ways in which its main surface features have probably come into being. In all there are seven chapters:—

(1) The Geological History of the Ocean.
(2) Classical Geography of the Ocean.
(3) The Crossing of the Ocean.
(4) The Circumpolar Regions.
(5) The Atlantic Ocean.
(6) The Pacific Ocean.
(7) The Indian Ocean.

In reviewing such a work one is not able to compare it with others of a similar type; it is, so far as we know, unique in subject matter. Students of geology and terrestrial tectonics will realise the vast amount of reading that must have gone to the production of such excellent chapters as those in which the geological histories of the various oceans are dealt with. No less pleasing are those in which the author sets out in lucid manner an account of the development of ideas as to the size and shape of the earth — as recorded by classical writers. The ideas of the Greeks as recorded in HOMER, the advances in knowledge due to the "Physical" philosophers THALES, ANAXIMANDER, PYTHAGORAS and their successors are very well presented. A clear explanation is given of how ERATOSTHENES measured the size of the earth with such remarkable accuracy, and we particularly

enjoy Professor JOHNSTONE's stimulating accounts of the voyagings of the Phoenicians. His speculations concerning their amazing voyages — the circumnavigation of Africa, their penetration into the Pacific from the West, the possibility that they reached Central America, their possible sojourn in Easter Island, the relics of their agricultural activities as they went "bit by bit" round Africa — all these matters make reading of first class interest.

It is no reflection on the book as a whole when we express the opinion that many readers will probably enjoy the first chapter best. Here we find a very well balanced and clear account of the different theories which have been adduced to account for the Earth's origin. Many popular theories are rejected (Chamberlain's amongst them), Professor JOHNSTONE holding to the view that the earth had all its material at the start; it began, we are told, as a mass of incandescent gas and not as an assemblage of cold meteorites. The Uranium/Lead ratio estimate of the earth's age (1.3×10^9 years) is accepted. The much discussed Wegener hypothesis is rejected, and the once cherished theory that ocean basins have been permanent throughout geological time is ruthlessly jettisoned. The author's treatment of the latter theory is admirable — his study of the history of the Pacific (involving discussions of insular arcs, foredeeps consequent on geo-synclinal marginal warpings, central "shallows" with debris of a one-time Pacific Continent) is excellent.

Much is made of the thesis that the absolute volume of the hydrosphere has grown considerably during past ages owing to the accession of juvenile waters (magmatic in origin). The bearing of this on the amount of dry land in the earth's surface is discussed. The converse effect of ice ages in withdrawing water from the oceans to form ice caps is dealt with. It might have been an advantage if the author had indicated roughly the order of the ocean shallowing so effected. We believe estimates (? NANSEN) have been made which would put the shallowing of the oceans consequent on the formation of the Quaternary ice-caps — at 130 metres. The formation of coral reefs is discussed in connection with this idea of ice-age shallowing of the oceans. The omission of any reference to the "aftermath" of an ice-age in so far as land and sea distribution in the ice-cap areas is concerned is, we think, a matter which might be remedied in a future edition. Thus Scandinavia has not yet finished rising after the disappearance of its load of ice. It might be considered in some quarters that Professor JOHNSTONE's rejection of the tetrahedral deformation theory of distribution of terrestrial land and water is too summary, and there are geologists who would not subscribe to his opinion that our known sedimentary strata cannot afford a close analogue to deep sea oozes.

There are numerous points which one would like to discuss were space available; for the book as a whole we have nothing but praise and we hope that the author will some day set himself the task of writing a history of our European seas.

The volume is well produced and the only apparent errors we have noticed are as follows:—

page 6. — 8th line up, for "by" read "of".
page 79. — The example about deviation is wrong.

page 116. — 20th line down for "fig. 19" read "fig. 17".
page 142. — 6th line down, for "degree" read "minute".
page 191. — 7th line up, for "depths" read "debris".

The passage on p. 81 regarding the voyage of Columbus is obscure. The date of sailing from Gomera, 6th Septh. 1492, should have been given, since the voyage from Spain to Gomera is not counted in when it is stated that the voyage lasted 35 days.

For the convenience of readers we suggest the following insertion:— On page 180 preceding (1) insert "see fig. 37".

J. N. C.

W. R. G. Atkins. Notes on the Preservation of Fishing Nets by means of Copper Soaps. Journ. Marine Biol. Association, 1926, N. S., Vol. XIV, No. 1, pp. 63—69. With 1 Figure in the Text.

The preservative effect of copper oleate on various forms of fishing gear is being actively investigated. In the present paper, Dr. Atkins describes further experiments carried out at Plymouth. His material was the silk and the hemp "stramin" from which plankton tow-nets and young fish trawl-nets respectively are constructed. The life of a silk net is very considerably prolonged by treatment with a solution of 10 per cent copper oleate in petrol or benzol. Good results were also obtained with stramin. All silk tow-nets used at Plymouth or issued to other institutions are now treated with copper oleate or with a mixed copper soap. Taylor and Wells have shown that the soap is retained by the fibre for a longer period if a certain proportion of tar is added. This result was confirmed at Plymouth. The use of 1 per cent of mineral oil or 5 or 10 per cent of resin as binding agents also had beneficial effects. The resin has a tendency to clog the meshes of fine silk if a stronger solution than one half per cent is used. The cost of treating a 35-lb. herring net with a 10 per cent solution of copper soap in benzol is estimated at 13s. 3d., with a 5 per cent solution, 11s. A method of preparing the soap in liquid form, by dissolving it, with the necessary amount of resin, in carbon tetrachloride, is described.

R. S.

Marie V. Lebour. The Euphausiidae in the Neighbourhood of Plymouth. III. *Thysanoessa inermis*. Journ. Marine Biol. Association, 1926, N.S. Vol. XIV, No. 1, pp. 1—11. With Plates I—V.

The author deals with material from the Atlantic Slope, English Channel and Iceland and agrees with Dr. H. J. Hansen that the two species *T. inermis* and *T. neglecta* are only forms of the one species distinguished by the length of the appendages. The fully grown individuals appear to migrate from the deeper to the shallower water in the spring for the purpose of breeding. The eggs, nauplii, metanauplius, three Calyptopis stages, fourteen Furcilia stages and twelve Cyrtopia stages are described. Two Furcilia stages, the seventh and tenth, were not observed, but their existence is inferred. The development of *T. inermis* is com-

pared with that of *Nyctiphanes Couchii* and *Meganyctiphanes norvegica* already described by the author. These three species are the only euphausiids known to occur in the English Channel and are an important constituent of the food of several fishes, especially hake and herring.

R. S.

W. de Morgan. Further Observations on Marine Ciliates Living in the Laboratory Tanks at Plymouth. Journ. Marine Biol. Association, 1926, N. S., Vol. XIV, No. 1, pp. 23—53. With 28 Figures in the Text.

In the present paper the structure of the following seven species of marine ciliates, living in the Laboratory tanks at Plymouth, is described:— *Trachelocerca phoenicopterus* Cohn, *Uronema marina* Dujardin, *Cyclidium glaucoma* O. F. Müller, *Blepharostoma pigerrima* (Cohn), *Holosticha rubra* (Ehrenberg) var. *flava*, *Holosticha multinucleata* Maupas, and *Lembus elongatus* (Clap. and Lachmann). Some notes on habits, food and synonomy are included.

R. S.

Michael Graham and J. N. Carruthers. The Distribution of Pelagic Stages of the Cod in the North Sea in 1924 in Relation to the System of Currents. With a Section on The Food of the Pelagic Young Cod by H. H. Goodchild. Ministry of Agriculture and Fisheries, Fishery Investigations, Ser. II, Vol. VIII, No. 6, London, 1926.

This paper is a neatly made and briefly written record of a series of cruises made in 1924 in the English Fishery research steamer "George Bligh", but the authors have considered also a great amount of evidence from other sources likely to affect the occurrence and biology of the cod fry, which evidently formed the main or only object of the four cruises considered: (1) 4-11/4, (2) 1-8/5, (3) 29/5-1/6 and (4) 5-8/7.

Mr. Graham, who was presumably responsible for the planning of the cruises, had laid out the courses so as to sample the areas where cod fry were especially to be expected, and where they were thought to be missing. The basis for the expectation of cod fry in certain areas was the wind and driftbottle data ably analysed by Mr. Carruthers whose definite forecasts of the probable distribution of the fry were to be compared by Mr. Graham with the catches of fry actually obtained. It must be said that the agreement found is very good, and it is fairly established by this research that one can safely regard the cod fry as passive passengers with the currents, and that the loss of fry from the North Sea to other areas probably is small, the Skagerrack being in 1924 the only direction observed where North Sea fry went out, no fry being observed farther west than near the line Hanstholmen—Lindesnes (Naze of Norway). Even if it thus seems to be established that no fry reached the Norwegian Coastal Current directly from the North Sea, this current might well carry a good quantity derived indirectly from the North Sea by way of the Skagerrack, just as our West Coast probably receives most of its sprat fry by the "Baltic" current from the Skagerrack and from the North Sea

The correspondence between Mr. CARRUTHERS' predictions of where the fry should occur and Mr. GRAHAM's catches is aptly brought out in a series of very instructive charts. The only drawback is that the explanation of the letters in the charts is not given in or under these, but in a note hidden on p. 9. The charts would also have been more easily consulted if a few station numbers had been denoted, say every fifth. These are the only criticisms I would venture against this interesting report, which reflects great credit on the authors and also on the Fisheries Laboratory, which has been able to commission three workers to tackle a definite and limited object from different sides at one time. There are few countries possessing so many marine research workers that such a thing could be thought of, and fewer still where the workers would consent to work so unreservedly together.

The nature of the food of Cod fry is clearly and sufficiently worked out by Mr. GOODCHILD, and the results conform very well with conditions observed on the coast of N. Norway, i. e. that the diet of cod fry almost wholly is composed of small or young calanoids, the other elements being rare and apparently only occasional. While, however, in the North Sea *Temora* and *Pseudocalanus* seem to be the most important fry food animals, in N. Norway it is the younger stages of *Calanus finmarchicus*.

In discussing the carefully executed measurements of cod fry caught during the four cruises Mr. GRAHAM demonstrates the curious fact that the demersal fry were much bigger than the pelagic fry caught at the same time (July). It is seen from the measurements that the fry takes to the bottom in June.

OSCAR SUND.
Bureau of Fisheries.
Bergen 15 june 1926.

F. BARANOV. On the Question of the Dynamics of the Fishing Industry. Bulletin of Fishery Economics, No. 8, Moscow, August, 1925. (In Russian)[1]).

The question of the fish content of the sea is one which has aroused great interest in recent times, owing to the enormously increased yields that have been obtained since the advent of the steam trawler, and the possible depletion of the stocks consequent upon this. Prof. BARANOV's paper is an attempt to envisage the probable results of intensive fishing, and to indicate a rational basis for the proper exploitation of the natural resources of the fishing grounds. The author holds that in an unfished basin there would be a constant stock of fish, determined by the total nutriment available. If now a fishery be established, the capture of some of the stock releases a corresponding amount of nutriment which will produce more stock. This new stock will, however, be less in total and individual weight and younger in age than that removed. If the fishery be uniform from year to year, it follows that ultimately there will be reached a stable condition, when the consumption of nutriment for the maintenance of the uncaught stock, plus that used for the production of the portion annually removed, is just equal to the total annual production of nutriment in the basin; whence it follows that the annual catch will be

stationary. Variation in the annual amount of fishing will be reflected inversely in the amount caught and its size-composition.

By this conclusion, the theory that the natural stock of fish should be regarded as capital of which only the interest should be taken is held to be disproved, and for it is substituted the idea that natural stock and fishing are incompatible, and that the residual stock is a variable quantity dependent upon the intensity of fishing. It should be noted that intensity of fishing includes an allowance for other kinds of mortality.

A generalised theory of this character is extremely difficult of proof in the present backward state of precise knowledge as to the expenditure of fishing power in the various regions. In default of better data, the author has chosen the records of English steam trawlers fishing in the North Sea, and calculated therefrom what would have been the catches of plaice each year since the war by these vessels, according to his formulae. In so doing he is in effect treating the catch of these vessels as if it were drawn from a total stock which is not subject to interference by other vessels, whereas during the period dealt with, English steam trawlers accounted for only from 35 per cent. to 54 per cent. of the annual total catch from the North Sea. In view of this, it is rather surprising to find that the theory does in fact produce a good fit with the recorded landings. If, however, an attempt be made to apply the theory to the similar data for haddock, or for total bottom fish, or even to plaice taken in the years prior to the war, the results are not satisfactory.

In conclusion, the author postulates that an essential work of the first importance is to place on a proper high level the systematic recording of the magnitude and qualitative constitution of the catches, and of the organisation for the capture of the fish. T. Edser.

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[1]) The Ministry of Agriculture and Fisheries, London, has had an English Translation of this paper prepared.

Current Bibliography.

Prepared by the Editor.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. ALLEN's Selected Bibliography published in Nos. 1 and 2 of the Journal, and since reprinted.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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Note.

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